POWER PLANT ENGINEERING

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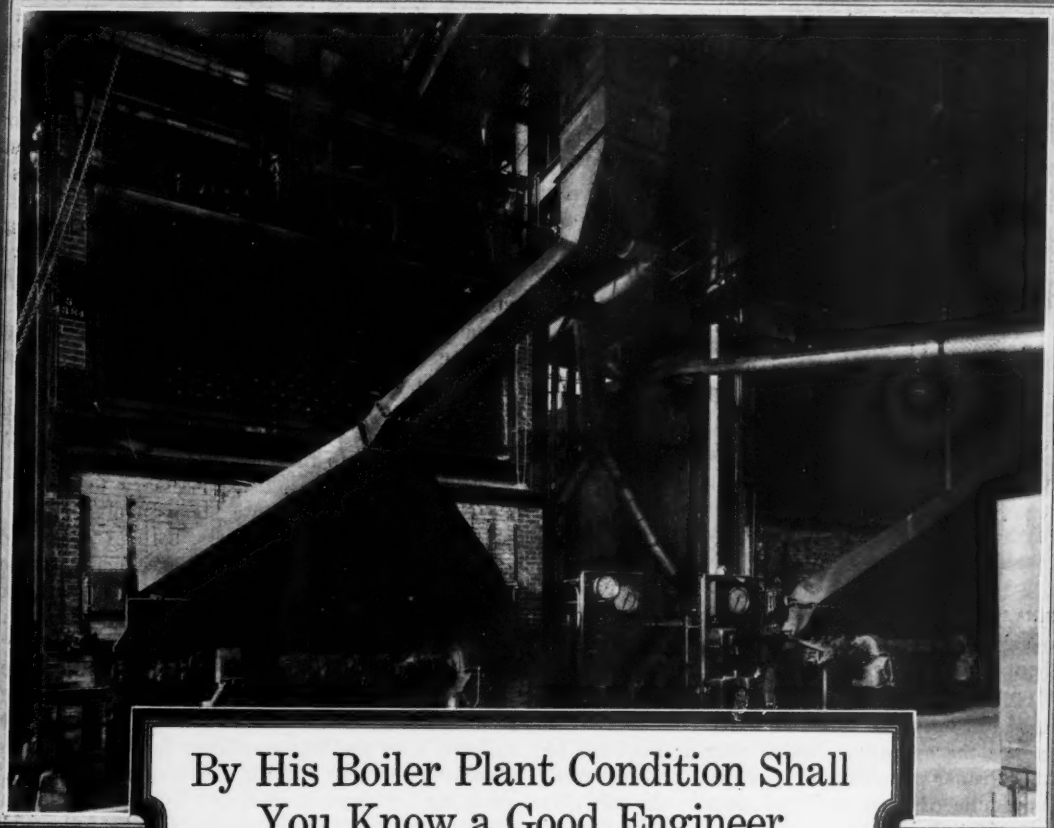


By His Boiler Plant Condition Shall You Know a Good Engineer

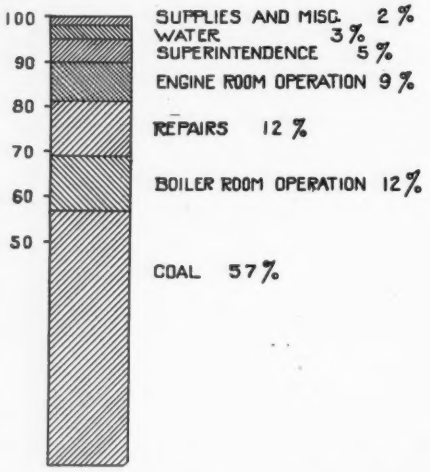
Coal Dust and Ashes have always been considered as inseparable from the boiler room; but progressive engineers are coming to feel that they are a mark of bad housekeeping. Dust and ashes will be made to a certain extent, but need not be let to accumulate. A clean, light room is a joy to the beholder, an inspiration to the workers therein and indicates a plant economically operated by a wide-awake engineer.

Boost the Economy of Your Boiler Plant

KEEP ACCURATE RECORDS AND STUDY THEM; ANALYZE EACH STEP OF OPERATION FOR LOSSES; USE EFFECTIVE ACCESSORIES EFFECTIVELY; YOUR DOLLAR OF BOILER ROOM EXPENSE WILL HAVE MORE USEFUL PENNIES IN IT

IN STRIVING to secure minimum cost of power production, the boiler room offers the best field for our efforts. There the most dollars of the cost of producing power are spent, also there is the greatest chance for waste by careless operation. Accessories for keeping track of losses and reducing them can, therefore, be used profitably.

Percentages of cost vary in different plants, but for a plant of from 500 to 2500 hp. the cost of fuel will be about 57 per cent of the total operating cost, the cost of water about 3.5 per cent, and the cost of operating the boiler room including the handling of coal and



PERCENTAGE OF COST OF POWER PLANT OPERATION

ashes about 12.5 per cent. It is easy to see that here is a great opportunity for loss unless all operations are carried out as efficiently as possible.

What are the operations which may or may not be efficient? Proper handling of the fuel and ashes so that a minimum of unburned fuel goes to the ash pit; supplying air sufficient to allow complete oxidation of the fuel elements, but not in such excess as to carry undue heat to the chimney; transferring heat from the gases to the water effectively; handling the chimney gases so as to reclaim as much of their heat as possible, and the steam and hot water so as to lose as little of their heat as possible. With the detail of these operations properly attended to, we may be sure of getting good value for each dollar of boiler room expense.

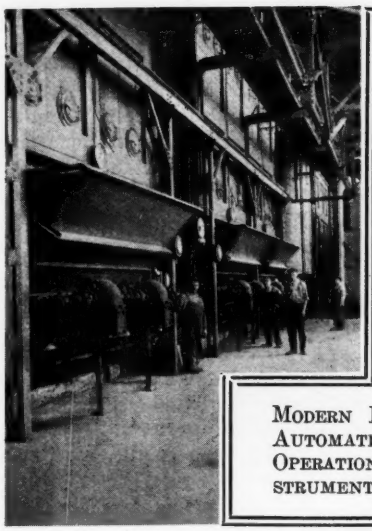
But how may we know that each boiler-room dollar is yielding proper return? Evidently the first thing needed is a standard by which to measure performance; a limit of results above which we may not reasonably expect to go. This involves a knowledge of the theoretical limits of efficiency, and how these are modified by practical conditions; and for daily operation these practical limits must be determined for each plant by trial. This involves testing and observation of results, to find where the losses occur and how far they can be reduced. And testing and recording results involves the use of accessories in the form of instruments; while cutting down waste often means the use of devices and apparatus designed to catch the wily heat unit and lead him captive back to the job he is trying to sidestep.

Accurate knowledge of performance can come only from accurate records. Such records require instruments that indicate and record correctly, careful reading of the instruments and observation of the action of the apparatus in the plant and systematic study of the records to interpret their meaning in heat action. To gage daily or monthly performance the records of present and past performance must be compared with each other, with those from similar plants and with the theoretical possibilities. For such comparison, graphic charts of the ways that energy is used are of great assistance, while graphic log sheets help to emphasize lapses from ideal conditions of operation.

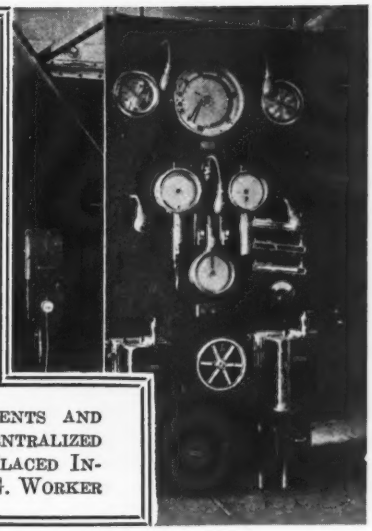
Any apparatus, whether intended for recording data or for cutting down losses, which is not properly cared for and used is wasted investment and is not worth while. But more than that, apparatus must be properly chosen, installed and operated with a clear understanding of why it is there and what it is expected to accomplish or it will fall far short of its purpose. And in order that the system of records and operation be economical, it is essential to understand the degree of accuracy needed in the records taken.

To hunt out losses, it is necessary to divide plant operation into the separate steps involved, and study each step as to its effectiveness, both in itself and as a part of the whole operation. Three main divisions of plant operation seem to present themselves, naturally: Operation of the furnace, including the supplying of fuel and air, proper mixing of air and combustible gases, maintaining temperature in the combustion chamber, and securing best conditions for the transfer of heat from the gases to the water. Handling the water so as to have it in the best condition for boiler feeding, for absorbing the heat and for conversion into steam. And handling the steam so as to get from it the maximum of desired result. These divisions will be followed in the following pages. The effort will be, at all times, to show what accessory apparatus may be used to advantage, and how it should be used to accomplish reduction of waste and secure the great savings that can be made in a properly operated boiler plant over one which is carelessly handled.

TESTS MADE at a large water-gas plant in Illinois by W. A. Dunkley, gas engineer, of the United States Bureau of Mines, using coal from No. 2 Illinois seam as generator fuel and operating with waste heat boilers, showed that approximately 12 per cent of the heat introduced as fuel was recovered by the boilers, the steam generated corresponding to about 600 boiler horse power, more than enough to operate the gas sets. Without the waste heat boilers, this energy would have been totally wasted. Recoverable heat was still going to waste.



Conditions Which Affect Operation of the Furnaces In Your Boilers Should Be Given Careful Study



MODERN RECORDING AND REMOTE-CONTROL INSTRUMENTS AND AUTOMATIC CONTROL DEVICES HAVE MADE THE CENTRALIZED OPERATION OF BOILER PLANTS FROM CONVENIENTLY PLACED INSTRUMENT BOARDS A GROWING PRACTICE. BY JOSEPH G. WORKER

IN THE OPERATION of the boiler room the most pronounced and important strides have been in the development of methods for controlling the factors affecting boiler operation. The further development of this control is no doubt going to be an important trend for the next few years. The boiler room must be placed under control the same as electrical apparatus and the turbine room for central station operation.

Acknowledging, as we may, that the boiler and stoker problem is not as simple as the electrical end of the station, nevertheless, the boiler room equipment must be developed and designed so that the problems that now seem insurmountable can be solved. A few years ago about all that a fireman had to help him determine the condition of boiler operation was a pressure gage. He was employed and paid according to his capabilities of "keeping up the steam." It is surprising the number of stations today that are not equipped with instruments and apparatus for indicating furnace conditions.

When the load increases on a particular boiler everyone knows that the fireman must get busy and feed more coal onto the grate. As soon as he does this he finds it necessary to increase the volume of air necessary to burn this larger amount of coal; the draft must then be regulated for the new conditions; and just as soon as the fire starts building up, clinker trouble is encountered that again changes all furnace conditions; holes appear in the fire, which necessitates careful observations.

All of these things happen in the furnace of a boiler when burning coal and even though it is not possible to control all these variables from a particular point, it is hoped that the development of control apparatus and instruments will proceed to such a point that it will not be long before all of these factors and conditions in the furnace can be controlled from one station the same as the electrical end is now being done.

Figure 1 shows the relation between coal, air, draft, CO_2, etc., when the load varies on a boiler with underfeed stokers. When the boiler is operating at rating, for example, the stoker is burning about 2400 lb. of coal as fired per hour, requiring 11.6 lb. of air per pound dry coal. The flue gas temperature is approximately 420 deg. F.

Supposing the load on the boiler changes to 300 per cent of rating; that is, the boiler is developing just three times its former rating. By referring to the chart it will be noted that instead of burning 2400 lb. of coal as fired per hour, the rate of combustion has increased so that the stoker is now required to burn 8400 lb. of coal as fired per hour. This means that instead of burning 22 lb. of coal as fired per square foot of grate surface per hour it is required to burn nearly 80 lb. This means that the volume of air must increase and correspondingly the stoker wind box pressure must be increased. At this higher rating, of course, the efficiency will drop somewhat and the flue gas temperature would be about 700 deg. F. instead of 420 deg. F., when the boiler is operating at normal rating.

Every boiler plant should have a set of tests conducted in order to establish a characteristic operating chart somewhat similar to Fig. 1, and when burning the grade and size of coal that is generally used in the plant. These tests will then establish the characteristic curve of the plant and what the requirements will be at different loads in the boiler. When the plant is working say 50 per cent above normal operation, the operator should be in a position to know the amount of coal that should be fed to the furnaces, the increased air volume that would be required to burn this amount of coal, what the draft for the particular boilers should be and an endeavor made to maintain these conditions, because he will know then that when operating under these conditions the highest economy can be obtained.

It was difficult a few years ago to get the management interested in making the investment in instrument equipment to place on the boiler units so that all of these conditions could be established and under the control of the operator. Probably the reason for this was due to the fact that a large number of plants purchased one or more instruments, and as soon as the novelty wore off the instruments were left to go without attention, with the result that it wasn't long before a visit by the manager indicated that they were of no use. He was right, for an instrument that is not kept in proper

repair and enough interest placed in what it indicates is not worth purchasing and going to the expense of putting into a plant.

Boiler room instruments, however, and their use should not be condemned on this account. There is no question but what the trend is for even more minute control of the boiler room than has been in the past. On account of varying conditions the present modern power station now has control boards connected with unit boilers. Such a board is shown at the right in the heading of this article which not only shows the steam pressure

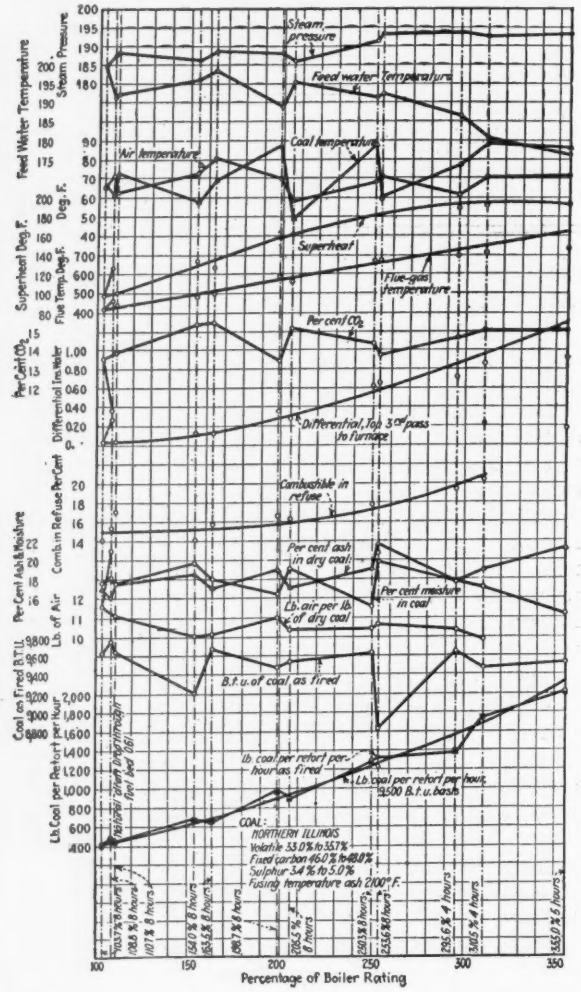

Steam pressure
Feed water Temperature
Air temperature
Coal temperature
Superheat
Flue-gas temperature
Per cent CO2
Differential, Top 3rd pass to furnace
Combustible in refuse
Per cent ash in dry coal
Per cent moisture in coal
Lb. air per lb. of dry coal
B.t.u. of coal as fired
lb coal per retort per hour as fired
Lb coal per retort per hour 9500 B.t.u. basis
COAL: NORTHERN ILLINOIS
Volatile 33.0% to 35.7%
Fixed carbon 46.0% to 48.8%
Sulphur 3.4% to 5.0%
Fusing temperature ash 2100° F.
Percentage of Boiler Rating

FIG. 1. PERFORMANCE TEST CURVES FROM 100 TO 350 PER CENT OF BOILER RATING—BURNING LOW GRADE 9500 B.T.U. ILLINOIS COAL ON UNDER-FEED STOKERS, 556-HP. B. & W. BOILER

but also has a steam flow meter. The draft over the fire and at the damper is shown. A motor control regulates the amount of coal that is being fed to the boiler. The air control wheel regulates the volume of air that is being forced through the grates. In fact, the operator has everything at hand properly to control the factors that affect the economy of the stoker and the boiler. This shows the modern control board at the unit itself; but there is no question but that the trend is going to be, that either a group of units or possibly the whole boiler room will be controlled from one point. The stoker equipment, auxiliary equipment and other equipment that makes up the boiler room part of the station will have to be developed to the extent that it will be possible to control it from a central station.

If pulverized coal is going to show better results than stoker fired boilers that most modern stations are now equipped with, it will be on account of the fact that it is more easily controlled from a central point. This does not mean that it is going to be difficult to control stoker fired boilers because there is no question but that these different factors affecting efficiency can be controlled if they are developed a little more than they are at the present.

Mortality rate of damper regulators, draft gages, etc., has been high, not on account of the fact that they were of no use in the boiler room, but due to the fact that they were somewhat ahead of the development in the art of regulating the boiler room conditions. The different items connected with the operation of a fire could not then be regulated. If the regulating devices were thrown into discard and no further attempts made

TABLE I. COMBUSTION RATES RECOMMENDED FOR VARIOUS FUEL CONDITIONS FOR FORCED DRAFT UNDER-FEED STOKERS

Combustion Rate per Sq. Ft. per Hour Dry Coal	EASTERN COAL	PITTSBURGH COAL	ILLINOIS COAL	IOWA COAL	LIGNITE
	F.C. 73 Vol. 17 Ash 6 S 1 Moisture 4 B.T.U.(Dry) 14300	F.C. 57 Vol. 30 Ash 7 S 2 Moisture 4 B.T.U.(Dry) 13500	F.C. 48 Vol. 30 Ash 12 S 3 Moisture 10 B.T.U.(Dry) 12200	F.C. 33 Vol. 27 Ash 25 S 4 Moisture 15 B.T.U.(Dry) 10400	F.C. 34 Vol. 33 Ash 10 S 1 Moisture 23 B.T.U.(Dry) 11500
Minimum for Continuous Operation	20 - 25	25 - 28	25 - 28	25 - 28	25 - 28
Recommended for Continuous Operation	30 - 38	32 - 40	30 - 38	28 - 35	30 - 35
Maximum for Continuous Operation	40 - 45	40 - 45	38 - 42	35 - 42	38 - 45
Recommended for 3 to 4 Hr. Peaks	50 - 60	50 - 60	45 - 50	42 - 45	45 - 60
Maximum for 3 to 4 Hr. Peaks	60 - 65	60 - 65	50 - 55	45 - 47	50 - 55
Maximum for One Hr. Peaks	70	70	60	50	60

to correct the root of the trouble and the cause of not being able to provide proper regulation, we would have made little progress.

That proper instruments be installed to show the conditions under which the units are operating should be insisted upon by the management of any boiler plant; also insist that the equipment installed be capable of regulation; and all engineering effort in the future should be toward the remote control of the boiler room from a control room the same as the present developed control room of the electrical end of the station. This is possible and it will not be many years before all boiler equipment will be controlled just as easily as any other kind of machinery.

All plants should be, and in most cases probably are, designed for a certain per cent of normal operation. In the matter of burning coal the minimum combustion rate is usually established that is best for continued operation. Under average operating conditions the efficiency of the equipment will drop off rapidly at combustion rates below the minimum that the plant was designed for and, unless it is absolutely necessary, provision should not be made for such operation. Referring to Table I, giving the combustion rates recommended for various fuel conditions for forced draft under-feed stokers, it will be noted that the recommended continuous operation for eastern coals is from

30 to 38 lb. of coal per square foot of grate surface per hour; while it is shown that for central stations and industrial plants where variable loads may be required, it is possible to operate satisfactorily for from 3 to 4 hr. up to 50 and even 70 lb. of coal per square foot per hour.

Table II shows the recommended combustion rates for chain grate stokers. It should be noted that this covers natural draft stokers. Forced draft chain grate stokers, especially with Illinois coals, do about 10 lb. per sq. ft. of grate surface better than the figures given. A rate of combustion of 45 lb. per sq. ft. of grate surface per hour for Illinois coals on forced draft chain stokers is a pretty good average to figure on. Very few forced draft chain grate stokers are doing any better than this, but for short periods there is a possibility of increasing this amount just the same as on any other stoker.

In order to know exactly how many pounds of coal are being burned per square foot per hour, it is necessary to know, and have instruments to indicate, the amount of coal that is being burned, and it should be

TABLE II. COMBUSTION RATES RECOMMENDED FOR VARIOUS FUEL CONDITIONS FOR CHAIN GRATE STOKERS

Combustion Rate per Sq. Ft. per Hour Dry Coal	EASTERN COAL F.C. 73 Vol. 17 Ash 6 S. 1 Moisture 4 B.T.U.(Dry) 14300	PITTSBURGH COAL F.C. 57 Vol. 30 Ash 7 S. 2 Moisture 4 B.T.U.(Dry) 13500	ILLINOIS COAL F.C. 48 Vol. 30 Ash 12 S. 3 Moisture 10 B.T.U.(Dry) 12200	IOWA COAL F.C. 33 Vol. 27 Ash 25 S. 4 Moisture 15 B.T.U.(Dry) 10400	LIGNITE F.C. 34 Vol. 33 Ash 10 S. 1 Moisture 23 B.T.U.(Dry) 11500
Minimum for Continuous Operation		20 - 22	20 - 22	20 - 22	20 - 22
Recommended for Continuous Operation		23 - 26	23 - 26	22 - 25	25 - 30
Maximum for Continuous Operation		30 - 33	32 - 35	25 - 30	35 - 40
Recommended for 3 to 4 Hr. Peaks		35 - 40	40 - 45	30 - 35	42 - 45
Maximum for 3 to 4 Hr Peaks		40	45	35	45
Maximum for One Hr. Peaks		40	45	35	45

within the possibilities of the operator to know just what rate of combustion is being used at any particular time during the day's operation.

Draft gages on each boiler are indispensable; that is, no boiler should be installed, with either stoker-fired equipment or hand-fired equipment, without a draft gage that will indicate not only the draft over the fire but the draft at the rear of the boiler or at the damper. Then again, when we say that draft gages are indispensable, it should be understood that they are to be kept in proper operating condition, with the fluid in the gages at all times, so that anybody passing through the boiler room and observing the boiler unit, will know the amount of draft at the damper and in the furnace.

When the operator knows the amount of coal that it is necessary to burn per square foot of grate surface per hour, on any particular kind of stoker that is being used, and knows the kind of coal to be burned, he can easily figure, from Figs. 2 and 3, the draft that would be required in the furnace to burn this coal economically. Figure 2 shows the amount of draft necessary for chain grates and other natural draft stokers. Figure 3 shows the wind box pressure required for underfeed stokers.

Draft is one of the most important factors in connection with boiler room operation and the increasing tendency to operate boilers with high over-loads has introduced another important factor in the draft problem. The higher rating often requires special arrangement for boiler baffling, introducing an element of uncertainty as to the draft losses at higher ratings, and unless

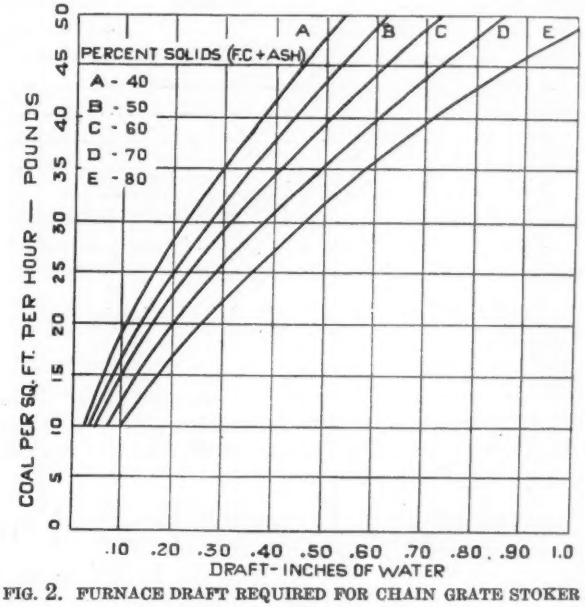


FIG. 2. FURNACE DRAFT REQUIRED FOR CHAIN GRATE STOKER FOR DIFFERENT COMBUSTION RATES

ample provision is made to indicate draft losses economical operation cannot be obtained. Therefore, it is not only necessary to have a draft gage to show the draft in the furnace, but there should also be a draft gage

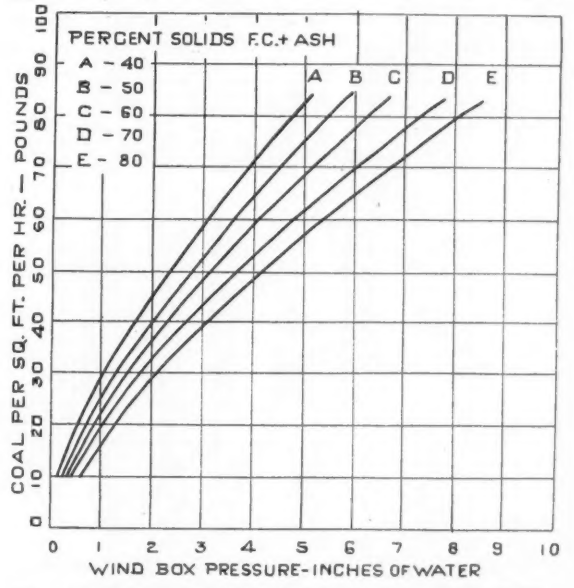


FIG. 3. WIND BOX PRESSURE REQUIRED FOR UNDER-FEED STOKERS FOR DIFFERENT COMBUSTION RATES

connected with the rear of the boiler to show at all times the draft loss through the boiler.

In general CO_2 is the final result of complete combustion of ordinary coal. The percentage in the flue gases is a guide as to how well the air is distributed through the fuel bed and whether or not there is an

excess or deficiency of air or an improper mixture of the air and gases.

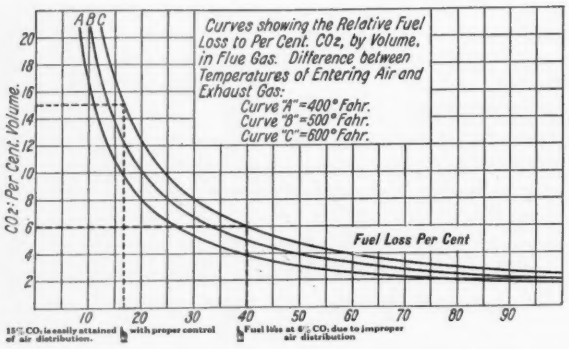


FIG. 4. RELATIVE FUEL LOSS AS INDICATED BY CO_2 INSTRUMENTS

Figure 4 shows how far one can get away from efficient operation without knowledge of the contents of the flue gases. The example shows that the relative fuel loss when operating very efficiently at 15 per cent CO_2 is about 17 per cent, while when operating at 6 per cent CO_2 the relative fuel loss is 40 per cent. It is not at all uncommon to go into plants that do not have instruments to show the analysis of flue gases and find that they operate anywhere from 5 to 7 per cent of CO_2. It is little wonder that they operate at this degree of inefficiency when so few plants have flue gases analysis arranged for or portable apparatus for frequent readings. Every plant should be able to tell at any time the temperature of the flue gases and the amount of CO_2 that is being obtained.

It is not uncommon to go into most plants and find upon analysis of the flue gases that the leakage of air through the old brick walls of the setting is so great that it seriously affects the operation of the plant. All of the air is being pulled through the bad brick work of the setting instead of through the grates. Of course, this gives excess air, all of which takes coal to heat the excess air to the furnace temperature.

Insufficient air is just as much a source of loss as excess air and this loss is more pronounced when part of the fuel bed is too heavily thickened.

Draft Gages and Their Proper Application

FOR MAINTAINING BEST FURNACE EFFICIENCY AN EQUIPMET OF GAUGES TO GIVE FULL KNOWLEDGE OF THE DRAFT CONDITIONS IS ESSENTIAL

TO SECURE the best possible furnace performance, i. e., the maximum obtainable efficiency at the desidered capacity, requires that the draft in the ash pit, over the fire, and in the uptake, be controlled with considerable nicety. If this control is effected manually, it is essential that the fireman be kept informed at all times as to the draft conditions obtaining in his

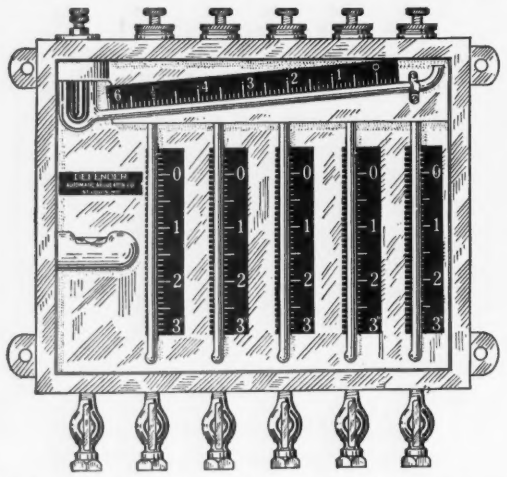


FIG. 1. VERTICAL TUBE DRAFT GAGES FOR MEASURING RELATIVELY LARGE PRESSURE DIFFERENCES

furnace. Should any change occur, he should know of it immediately and not have to wait until his pressure gage or safety valve tells him what is taking place. This information can best be brought to his attention by the use of draft gages.

As furnace drafts or pressures are quite small, being of the order of only a few inches of water, the most satisfactory method of measurement is by the "U" tube principle. Some gages, especially those used for testing purposes, are true "U" tubes; others frequently

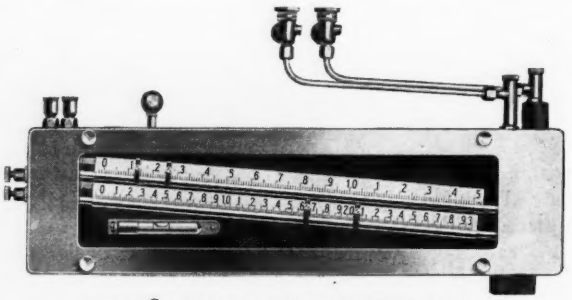


FIG. 2. DOUBLE-TUBE INCLINED GAGE

found as a permanent installation especially where the draft or pressure to be recorded amounts to several inches, are so constructed that the movement of the liquid level in one leg of the tube is calibrated to read the differential movement in both legs. A variation of this type, used where greater accuracy is required, is built with one leg of much larger sectional area than the other, so that the movement of the level takes place almost wholly in one leg. Such a gage is shown in Fig. 1. The movement in the small tube is thus practically doubled and is consequently much more easily read.

For small furnace differentials, the variation on a vertical column is exceedingly minute and therefore difficult to read even at close range. For such conditions, an inclined gage is used so as to magnify the movement. In the inclined gage, one leg is inclined from the vertical to within a few degrees (5 or 10) of horizontal. In addition, one leg of the tube is made of large area. The vertical movement for a given draft variation will

be the same as in the vertical tube, but the actual, the visible movement along the length of the tube will be multiplied by one over the sine of the angle that the tube makes with the horizontal (for 5 deg. this is approximately 11.5 and for 10 deg. 5.75). As a consequence, small draft variations are easily readable even at a considerable distance. For economy of space, this inclined leg is sometimes wound spirally around a cylindrical shell in which case the instrument is called a spiral gage.

For comparing the drafts at different points in the setting, two or more gages are used, frequently mounted together on a single frame. The instrument may be so arranged that one gage indicates the furnace draft and

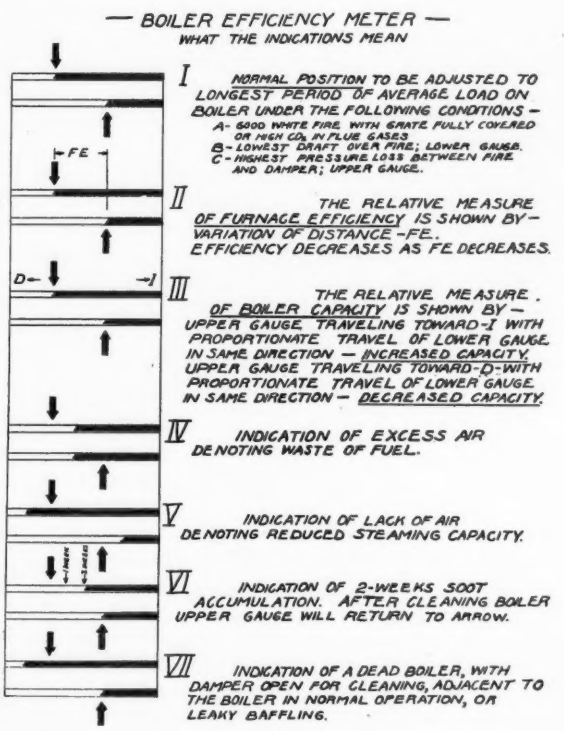

— BOILER EFFICIENCY METER —
WHAT THE INDICATIONS MEAN
FE
D
I NORMAL POSITION TO BE ADJUSTED TO LONGEST PERIOD OF AVERAGE LOAD ON BOILER UNDER THE FOLLOWING CONDITIONS — A- GOOD WHITE FIRE WITH GRATE FULLY COVERED OR HIGH CO_2 IN FLUE GASES B- LOWEST DRAFT OVER FIRE; LOWER GAUGE. C- HIGHEST PRESSURE LOSS BETWEEN FIRE AND DAMPER; UPPER GAUGE.
II THE RELATIVE MEASURE OF FURNACE EFFICIENCY IS SHOWN BY — VARIATION OF DISTANCE -FE-. EFFICIENCY DECREASES AS FE DECREASES.
III THE RELATIVE MEASURE OF BOILER CAPACITY IS SHOWN BY — UPPER GAUGE TRAVELING TOWARD -I WITH PROPORTIONATE TRAVEL OF LOWER GAUGE IN SAME DIRECTION — INCREASED CAPACITY. UPPER GAUGE TRAVELING TOWARD -D- WITH PROPORTIONATE TRAVEL OF LOWER GAUGE IN SAME DIRECTION — DECREASED CAPACITY.
IV INDICATION OF EXCESS AIR DENOTING WASTE OF FUEL.
V INDICATION OF LACK OF AIR DENOTING REDUCED STEAMING CAPACITY.
VI INDICATION OF 2-WEEKS SOOT ACCUMULATION. AFTER CLEANING BOILER UPPER GAUGE WILL RETURN TO ARROW.
VII INDICATION OF A DEAD BOILER, WITH DAMPER OPEN FOR CLEANING, ADJACENT TO THE BOILER IN NORMAL OPERATION, OR LEAKY BAFFLING.

FIG. 3. CHART SHOWING CONDITIONS THAT A TWO TUBE GAGE WILL INDICATE

one the uptake draft or the differential between the grate and uptake. Such a meter is shown in Fig. 2.

By running a series of tests on the boiler and furnace at various loads, changing the position of the damper, ash pit doors and over fire openings, if necessary, and the thickness of the fuel bed at each load, a series of draft and CO_2 readings may be obtained. There will thus be found a certain combination of drafts that will give the highest CO_2 without forming CO for every load. It will also be found that the relation of drafts will be about constant for all loads so that an index may be put on each scale to mark the points for best draft conditions at rated load. At other loads, the liquid level in each tube should be at equal distances above or below the indices for best results. Any variation from this relation will tell the fireman that all is not well in his furnace and further it will give him a pretty good idea as to where the trouble is.

As an example of what the gage will indicate: Both levels at the pointers show best efficiency at normal load. If both levels are raised by an equal amount an overload at best efficiency is indicated or if both are lowered an equal amount an underload at best efficiency is shown.

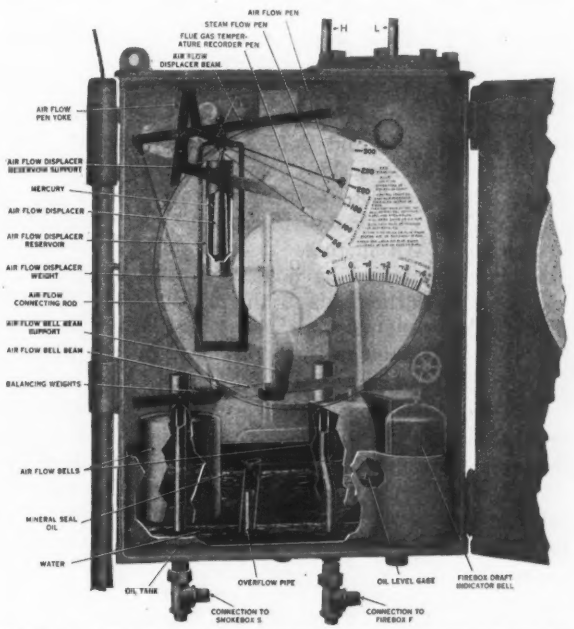


FIG. 4. AIR FLOW RECORDING METER COMBINED WITH STEAM FLOW METER

FIG. 5. FURNACE DRAFT RECORDER

When the damper draft decreases and the over-fire draft increases it is an indication of leaks in the baffling or clinkers or too thick a fire. In a hand-fired setting, this is the condition just after firing. After firing, the furnace draft will decrease and the damper draft will in-

crease until an unbalance in the reverse direction occurs just before the next firing period. If this latter unbalance persists, it indicates holes in the fire or a thin fire or excessive slag and soot on the tubes. The chart shown in Fig. 3, one that is furnished with such a meter, serves to indicate these conditions in a graphical way.

In Fig. 4 is shown a phantom view of a meter which indicates and records steam flow, air flow, and flue gas temperature and also indicates furnace draft. The air flow recorder is operated by the pressure difference between the fire box and uptake which varies of course with the rate of flow. This pressure difference is applied to two oil sealed bells suspended from knife edges on a beam which carries a displacement member immersed in mercury. An increase in the rate of flow of the gases is accompanied by a greater pressure difference which acting on the bells produces motion of the beam. The displacement member moves until its change of buoyancy balances the force produced by the pressure difference on the bell.

Flow of air is recorded as a certain per cent of the requirements with an allowable excess at rating. As the steam flow or rating increases, the air flow increases and, for best operation, by the same relative amount; therefore, for best efficiency the air flow and steam flow records should be coincident. At the time the meter is installed, a simple test is made on the boiler to determine the best operating conditions. At this point, the air flow pen is set to coincide with the steam flow. As long as these two pens keep together, conditions are as they should be; but when they diverge, it is an indication that the air supply is either below or in excess of normal. On this same chart may be recorded also the flue gas temperature and also the ash pit losses. In addition drafts at different points in the setting may be indicated.

Where it is desirable to have the draft readings apart from the meter a separate gage is used. This apparatus is operated on the same principle as the meter. The desired pressure difference between any two points in the furnace or between any point and the atmosphere is applied to two oil sealed bells suspended from a beam. This movement is communicated directly to a pointer which indicates on a suitable scale, the required draft. These gages are built to accommodate as many as 12 separate pointers.

It is sometimes desirable to keep a record of certain drafts in the furnace. This may be accomplished by the use of such an instrument as shown in Fig. 5. In this apparatus the differential movement of an oil sealed bell is transferred direct to a vertical spindle at the end of which is attached a recording pen. This pen records the draft in inches of water on a vertical cylindrical chart.

If a draft gage is to be of value to the fireman he must read it and read it at frequent intervals. This he will not do if it causes him any inconvenience. It is desirable then that the gage be so located, on a special panel provided for the purpose or on a building column, if one is at hand, that it may be easily seen from in front of the boiler. In many boilers these gages are located on the side wall of the boiler, near the front. This is a second choice position and should be resorted to only where absolutely necessary. A gage is of no value unless it is observed and for this reason the location is of quite as much importance as the gage itself.

Combustion Control Apparatus

AUTOMATIC REGULATION OF DAMPER POSITION, FUEL FEED, AND UNDER GRATE PRESSURE IS CONDUCIVE TO HIGHER FURNACE EFFICIENCY

WITH EITHER an insufficient or excess amount of air supplied to the combustible on the grate, there results a loss of heat; with too little air, combustion is incomplete, CO is formed and the difference in the heat liberated in the formation of CO and that in the production of CO_2 is lost. On the other hand, when excess air is present, while the combustion may be complete, some of the heat liberated is used to raise the temperature of the excess gases to the flue gas temperature and thus is lost. In the regulation of the air supply lies one of the most important means of increasing the amount of heat that may be realized from the fuel.

If furnace conditions remained constant, this regulation would be simple because the amount of air required for a given fuel would be constant. These conditions do not, however, remain the same for more than a few seconds at a time. The thickness of the fuel bed and also its density changes, the demand for steam and the rate of combustion are constantly varying and therefore the rate of feed of both fuel and air must vary. Where no method of automatic control is used the uptake damper is adjusted to supply enough air at maximum load, consequently for any less load there is waste.

There is, in every furnace, a condition of draft over the fire that is fundamentally correct. With this draft, the gases move through the boiler at a velocity permitting of maximum heat absorption. This over-fire draft should be kept constant and of such intensity that there is not a heavy influx of cold air through the brick work nor an excessive radiation of heat such as is the case when there is a positive pressure over the fire.

In order to maintain any predetermined over-fire draft, it is necessary first to regulate continually the uptake draft by means of the damper, and second the ash pit pressure must be controlled to compensate for the varying resistance to flow through the fuel bed.

DRAFT AND STEAM PRESSURE USED TO CONTROL COMBUSTION

ONE SYSTEM of combustion control uses two independent though correlated sources of control; boiler pressure and over-fire draft. Boiler pressure is communicated to a mercury reservoir which forms one leg of a "U" tube. Another reservoir located above the first at a height sufficient to balance the maximum steam pressure is connected by means of a pipe with the first. For instance, with a steam pressure of say 150 lb. gage, the distance between the mercury levels in the two legs

of the "U" tube would be 305.5 in., or about 25.5 ft. In the upper reservoir there is a float which rises and falls in direct proportion to changes in steam pressure. When this float raises, due to an increase in steam pressure, it lifts, by means of a yoke and connecting cable, the spindle of a four-way valve, admitting oil or water pressure on top of a plunger and releasing the pressure below. This plunger and the float are connected by a cable which passes under a pulley mounted on the control valve spindle, the movement of which is therefore controlled differentially by that of the plunger and the float. As the plunger descends it lowers the spindle of the control valve and cuts off the hydraulic pressure unless there is a continued rise of the float due to continued increase in steam pressure. Thus the movement of the plunger is gradual and its position is proportional to the boiler pressure at all times. The movement of this master control plunger is communicated

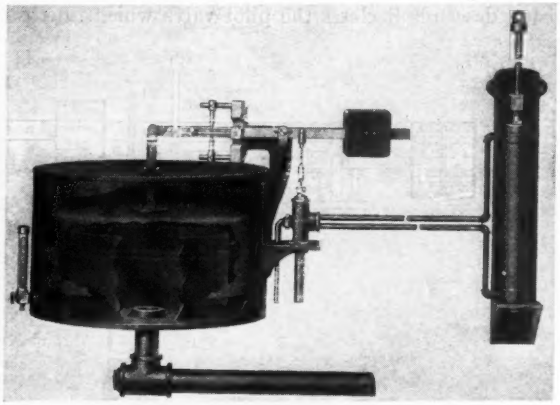


FIG. 1. A FOUR-WAY VALVE IS ACTUATED BY THE MOVEMENT OF AN OIL-SEALED BELL WHICH IS CONTROLLED BY THE OVER-FIRE DRAFT

to chronometer valves on the blower engine or turbine and on the stoker engine. These valves control the amount of steam supplied to these engines and hence the amount of air delivered to the furnace and the stoker speed.

Damper position is controlled by variations in the over-fire draft. This draft is communicated to the space under the bell of an oil-sealed gasometer, a phantom view of which is shown in Fig. 1, which is held in equilibrium by a counter weight. Any variation in over-fire draft will vary the position of the bell, and this movement is used to actuate a four-way valve controlling a hydraulic plunger, as in the case of the steam pressure control. The plunger movement is used direct to control the damper position.

Thus it will be seen that a reduction in steam pressure caused by an increase in demand will cause the steam pressure control to increase the under-fire pressure and to speed up the stoker. The resulting increase in pressure over the fire will act through the gasometer to open the damper.

Compressed Air Operated System

With another system of combustion control, in the event of an increase in the demand for steam, the boiler pressure drops and this drop is transmitted to a steam pressure controller which acts through the medium of compressed air to open the uptake damper. This greater damper opening increases the over-fire draft which in turn registers, through an over-fire vacuum pipe connected to the furnace air controller. The increase in vacuum lowers the oil level on one side of a "U" tube and with it a float. The downward movement of the

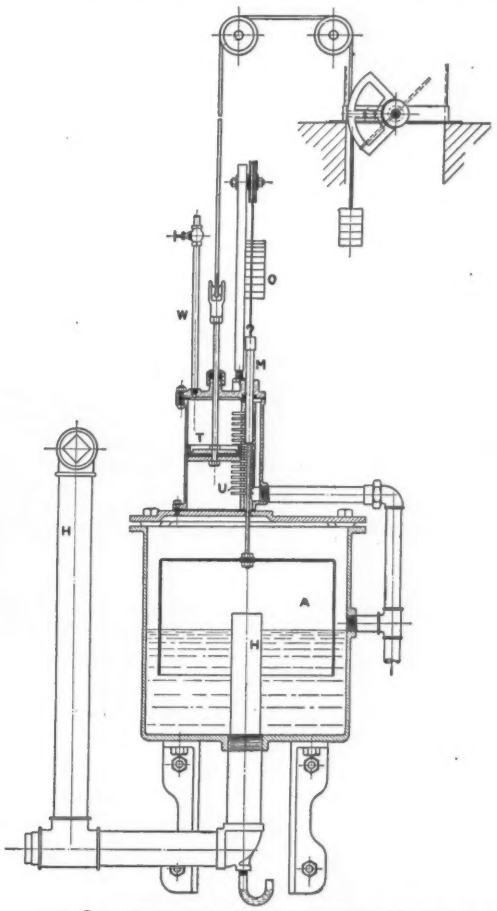


FIG. 2. OVER-FIRE DRAFT DAMPER CONTROL

float closes a leak port in the compressed air system. The consequent increase in pressure in the control system acts either to increase the furnace blower speed or open the blast gate sufficiently to build up the under grate pressure and bring the over-fire draft back to the original point.

Boiler damper operation and stoker feed are regulated by a steam pressure controller, actuated by variations of steam pressure in the boiler or header. This pressure is exerted on a bronze diaphragm and is opposed by a coil spring, the tension of which is adjusted for the steam pressure which is to be carried.

When the boiler pressure falls below the predetermined point the spring forces down the diaphragm and with it a steel stem. The downward movement of this stem opens a leak port in the compressed air line and allows a definite portion of the air passing to the damper and stoker controls to escape. The pressure on these controls is therefore lessened in proportion to the drop in steam pressure and the controls act to open the damper wider and to increase the speed of the stoker

engine. The opening of the damper will, of course, increase the over-fire draft and the furnace control will automatically act to increase the undergrate pressure, and to maintain the predetermined draft over the fire.

Over-Fire Draft Controls Damper Position

Operating mechanism of the system of damper regulation, shown in section in Fig. 2, consists essentially of a bell float, A, provided with a water seal, within a cylindrical chamber. The under side of the bell communicates by a draft pipe, H, with the combustion chamber so that the pressure under the bell is the same as that obtaining in the furnace. To the top of the bell is attached the spindle of a control valve, M. The weight of the bell and valve is counterbalanced by a small weight to produce equilibrium at any desired furnace draft.

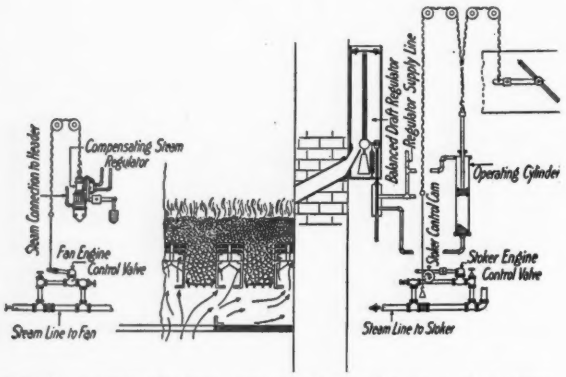


FIG. 3. DIAGRAMMATIC ARRANGEMENT OF THE BALANCED DRAFT SYSTEM

Above the float chamber is the operating mechanism proper which consists of a piston, T, and its cylinder. To the piston rod is attached a cable which is connected to the damper arm. The damper arm is counterbalanced by a weight so that there is always a tendency to raise the piston and open the damper. In the side of the cylinder there is a series of port openings, U, which surround the control valve. These port openings are sealed off on one side by the control valve, and on the other side by the piston. The top of the cylinder is always under a small water pressure and is connected by a small pipe line, W, to the water pressure line.

When water pressure is applied to the upper end of the cylinder, the piston is forced down until one port is open and the water pressure released. Water pressure above the piston will be just sufficient except when the piston is moving to balance the damper counterweight and the piston will maintain a position such that one port is partly open. In this way the movement of the control valve creates a corresponding movement of the piston and damper. Water passes through the open port down through the valve chamber, part flowing into the bell chamber to maintain a constant water level, the rest to the overflow line.

In case the furnace draft increases, there will be an increased vacuum under the float and it will be pulled down. This will also pull down the control valve, sealing off the valve control ports to the upper side of the piston chamber; water pressure above the piston will be increased and the piston forced down below the control valve, when one of the ports will be opened and the water pressure released. The control valve has thus forced the piston down and closed the damper sufficiently so that the predetermined draft is again obtained in the furnace and also under the bell, and the float members and counterbalance weight are again balanced.

Balanced Draft

Yet a different combination of control apparatus is employed in the balanced draft system. In this system, steam pressure controls the air supply and the furnace draft, the rate of fuel feed and the damper position. In the steam pressure controller, steam pressure acts under a weighted diaphragm. An increase in boiler or header pressure raises the lever arm supporting the counterbalance weight and with it a link which operates a pilot valve to admit hydraulic or pneumatic pressure on top of the main control piston. As this piston descends it closes the pilot valve which thus prevents any further movement of the control piston unless there is a continued rise in boiler pressure. This control piston is connected by means of a cable with the throttle valve on the forced draft fan in such a way that as the boiler pressure rises the steam supply to the fan engine is cut off and less air is delivered to the furnace.

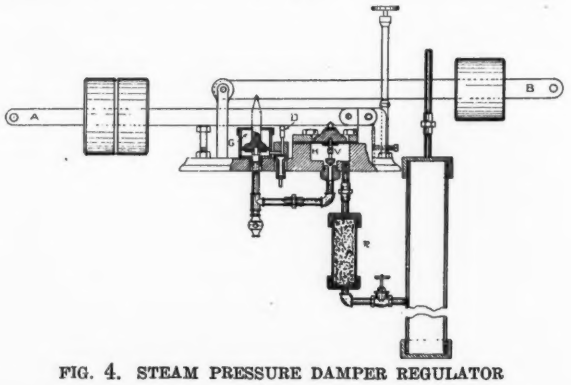


FIG. 4. STEAM PRESSURE DAMPER REGULATOR

This action necessarily alters the over-fire draft condition which will act on the furnace regulator. This regulator, shown diagrammatically in Fig. 3, consists essentially of a vertical plate or partition subjected on one side to the furnace draft and on the other to atmospheric pressure. The plate is weighted at the bottom and is supported at its center of gravity so as to be free to move about a horizontal axis. As it is usually desirable to maintain a slight draft over the fire, a spring is used to compensate for the pressure differential between the atmosphere and over the fire, and to hold the plate in a neutral position for any prescribed furnace draft. Attached to the plate at the point of support is a short arm to which is connected the stem of a pilot valve. Any movement of the plate, either in or out, operates this valve to admit pressure either above or below the piston working in the operating cylinder. The movement of the piston is transmitted through a connecting cable direct to the damper arm and also to a cam controlling the stoker engine.

Attached to the throttle valve of the stoker engine is a lever which rests on this cam whose outline is of a spiral form. As the cam is rotated by the control cable,

it raises or lowers the lever arm and admits more or less steam to the engine. The resulting increased feed offers a greater resistance to the flow of air through the fuel bed, the over-fire draft is increased and the balanced draft control acts to check the feed.

Steam Pressure Damper Regulator

For some classes of service where it is deemed desirable to control automatically only the damper position, usually some form of steam pressure actuated control is employed. The type generally employed is that in which steam pressure on a diaphragm is opposed by a lever and weight combination. In Fig. 4 is shown a section of regulator of this type, the action of which is quite simple. Boiler pressure is transmitted through the condensing chamber, which is full of water, and con-

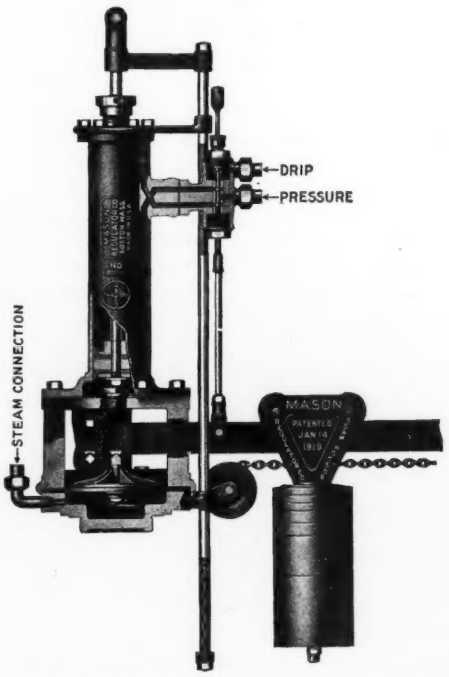


FIG. 5. STEAM PRESSURE CONTROLLED HYDRAULIC DAMPER REGULATOR

necting filter, R, to the weighted diaphragm, H, which controls a pin valve, V. An increase in boiler pressure beyond the desired point raises the diaphragm and closes the discharge valve, D, thus allowing pressure to build up under the plunger in cylinder, G. This plunger rises and carries with it the lever, B, to which is attached the cable to the damper arm. As this lever rises, it allows the damper to be closed by means of a weight. In the event of a reduction in boiler pressure, the action is reversed. Valve V is closed and Valve D opened, allowing pressure in the cylinder G to be dissipated. The plunger drops and with it the lever B.

Hydraulic pressure is frequently the motive power employed. Admission of this pressure to the operating cylinder is controlled by a four-way valve which, in some regulators, is actuated differentially by the weighted lever arm and the operating plunger. Thus every tendency to move the plunger, and with it the damper, is checked as soon as the movement begins and unless there is a continued change in boiler pressure the plunger movement ceases. The result is that the damper movement is gradual and its position is proportional to the boiler pressure.

In the regulator shown in Fig. 5, gradual movement is obtained by having the movement of the plunger shift the weight on the lever arm in such a way as to check the plunger. The result is practically the same as that to be had by differential control of the pilot valve.

One of the most important points in the design of damper regulators is to obtain a gradual movement of the damper. A simple full open or tight shut control is of little if any value. All present day regulators are equipped with some form of compensating device to check the damper movement unless there is a continued change in the controlling factors.

Unit Furnace Blowers

Constant Over-Fire Draft May Be Had by Varying Ash Pit Pressure to Suit Fuel Bed Resistance

CERTAIN advantages are obtained through the maintenance of a constant predetermined low draft over the fire. To keep this draft constant with a varying rate of combustion, thickness of fuel bed, and quality of fuel, in short, with varying fuel bed resistance, it is

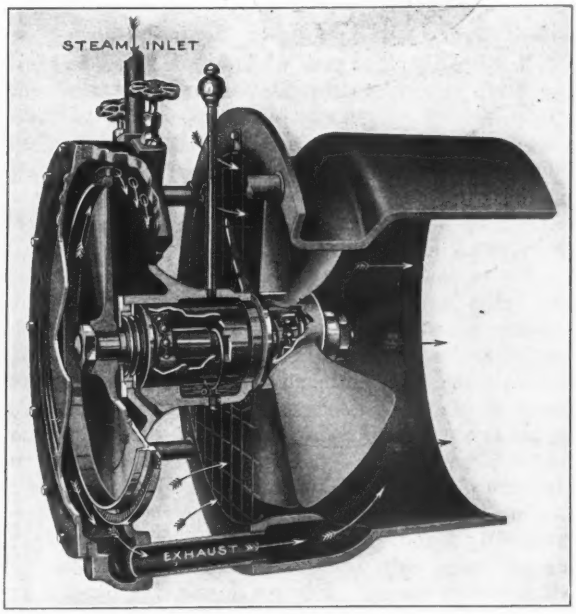


FIG. 1. IMPULSE TURBINE DRIVEN FURNACE BLOWER

essential that some means be provided for varying the under-grate pressure. By supplying a positive pressure under the grate the chimney is relieved of the work of pulling the air for combustion through the grate and consequently is capable of increased capacity. These results may be obtained by the use of either a forced draft fan and ducts or by a unit furnace blower.

Furnace blowers are of two general types; steam jet and mechanical. Steam jet blowers possess the ad-

vantage of being simple to install and operate and low in first cost, but steam consumption is likely to be excessive. For this reason their most common use is in plants requiring forced draft only for short periods during the day.

Mechanical furnace blowers are built directly into the walls of the furnace and therefore require but little space; they are compact and easily accessible for inspection and cleaning. Practically all such blowers employ the propeller type fan largely for the reason that changes in discharge pressure due to variations in fuel bed resistance have but little effect on the quantity of air delivered. This presents a certain advantage in design because it is almost impossible to determine beforehand just what the fuel bed resistance is going

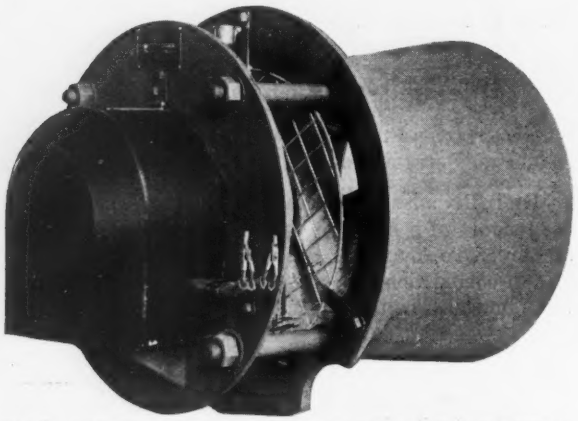


FIG. 2. MOTOR DRIVE IS USED WHERE HIGH PRESSURE STEAM IS NOT AVAILABLE

to be. Any change in demand for air, brought about by variations in the steam demand, may be met by varying the propeller speed. Speed variations may be effected by a regulator actuated by a change in boiler pressure or over-fire draft.

Motive power may be supplied either by steam turbine, electric motor, compressed air or belt drive, depending on which is the most easily available in any particular installation. In high pressure installations, steam is the most economical source of power, hence steam turbines are employed there almost exclusively; in the smaller sizes, a single-stage impulse turbine and in the larger a double-stage unit. For extra large installations, multiple units are used. In low pressure heating plants, the variable speed electric motor is most frequently found. Belt drive and especially compressed air are found only where there are certain special conditions of operation. Figures 1 and 2 show the two most commonly used types, Fig. 1 the steam turbine and Fig. 2 the electric motor.

Essentially the general construction is as follows: The fan casing is imbedded in and supported by the brick work of the furnace wall. From it is supported the turbine casing by means of studs and the exhaust pipe. The shaft with its bearings is mounted within the motor bushing. The complete motor is inserted as a unit into the housing of the turbine casing leaving an oil reservoir in the bottom of the housing. An oil ring hangs from the shaft into the oil chamber and serves to circulate oil through the bearings after which it is returned to the sump or reservoir. The shaft carries on one end the turbine rotor and on the other, the fan or propeller. The turbine casing is sealed so that no exhaust steam or water can enter the oil chamber and the oil chamber is also sealed to prevent the escape of oil or the admission of dirt or dust.

On account of the conditions under which they operate, so intimately associated with ash and dirt, particular attention is paid to the question of correct lubrication. The seals mentioned are provided for the express purpose of keeping the oil uncontaminated.

While the illustration shown depicts a central bearing with overhung rotor, the rotor may be supported between two bearings instead. The fan must of necessity be on the end of the shaft but it is so designed that the load will come as directly over the bearing as possible thus relieving the strain to a great extent.

Propellers are made with from four to eight blades depending on the size of the unit and the amount of air it is to handle.

The fan casing is so designed as to convert as much of the velocity energy of the air as possible into pressure energy, as that is the important factor governing the flow through the grate. In one type of blower guide vanes are used to increase the diffusion effect.

Among the more recent applications of the unit type blower is the multiple installation used in connection with the zone system of combustion on chain grate stokers using forced draft. One blower is installed in each of the separate wind box compartments. By this arrangement the pressure under each of the combustion zones, of which there may be as many as five or six to a stoker, may be varied individually to correspond to the varying air requirements and fuel bed resistance of each zone.

In the first zone, for instance, where the fuel bed has its maximum thickness and where the volatile constituents are being distilled off, the air requirements are greatest as is also the fuel bed resistance. Under this zone the pressure and the amount of air delivered should be a maximum. At the last zone the combustible matter has been almost wholly consumed and the bed is thin. Under these conditions the pressure drop through the grate is low; consequently the pressure under the grate should be low and the volume delivered also low. Each zone has a different set of conditions that may be properly satisfied by hand manipulation of the throttle valve. Gradual changes in the requirements of the furnace brought about by variations in the rate of fuel feed may be automatically compensated for by either an over-fire draft or steam pressure regulator which controls all blowers in unison.

With this type of installation it has been found possible to burn satisfactorily on a chain grate stoker some of the poorest grades of coal including anthracite culm, mine refuse, coke breeze, etc. Probably one of the greatest advantages of this system is that excess air, that demon of the boiler room, may be reduced to a minimum. Air is supplied only where it is needed and not through a bed of ash where almost none is required.

TOTAL PRODUCTION of gas and fuel oils during October was reported at about 4,000,000 gal. above the September figure, and amounted to 921,606,114 gal. Stocks of these oils on hand Nov. 1, were 1,368,748,880 gal.

Forced Draft Fans and Exhausters

Equipment for Pressure Systems, Automatic Control Methods, Power Required and Air Capacity, Proper Location and Drive Systems

FANS USED in the production of artificial draft for modern furnace installations may be classified according to two general types, i. e., centrifugal type fans and propeller type fans, depending upon whether the air is drawn in axially from one or both directions and discharged tangentially, or whether the air is discharged axially. In the latter case the blades are of the propeller type, hence the name.

Centrifugal fans, the type with which this article is primarily concerned, may be further classified according to style of blading. Fans having rotors with only a few straight or slightly curved blades, but with considerable length radially, are commonly known as steel plate fans; those having rotors with a comparatively large number of short curved blades are usually termed multivane fans.

Both the steel plate fan and the multivane types are used in modern power plant practice, although with the increasing use of high-speed motor and turbine drives the multivane construction is probably more common, particularly in connection with forced draft pressure systems. The behavior of any fan determines its applicability to meet the particular problem under consideration. The pressure characteristic of a stoker fan, for instance, should be a curve gradually rising from maximum capacity to no load. A curve of this kind showing the performance of a turbo-conoidal fan is shown in Fig. 2C.

Characteristics of Various Fans

Steel plate fans or, as they are sometimes called, paddle wheel types, are the oldest commercial type in use and are well suited to the requirements of forced draft systems because of their pressure characteristics. The steel plate fan is a slow-speed machine and is usually used on installations where direct connected engine drive is desired or in cases where a moderate priced fan is wanted. In cases where it is desired to use this type of fan in connection with turbine or motor drives, reduction gears may be employed. For equal capacity and efficiency the steel plate fan requires more space than the multivane type; its first cost, however, is usually less. Where first cost is of consequence and where ample space is available, the steel plate fan may be used to advantage.

Multi-vane type fans are made usually with four different styles of blading, enumerated as follows: (1) the forward curve, (2) the radial tip, (3) the partial forward curve, and (4) the full backward curve.

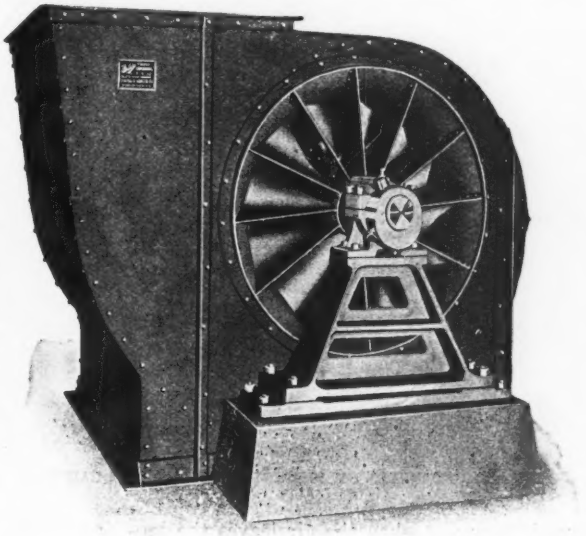


FIG. 1. TURBO-CONOIDAL STOKER FAN WITH INLET GUARDS

The forward curve in a fan blade has a distinctive action in that the rotational component of the air velocity leaving the wheel is actually higher than the rotational speed of the wheel itself. The result is a peculiar characteristic which tends to rise with increasing volume until a point is reached when the velocity through the wheel is so high that the air can no longer follow the blade. A typical characteristic curve of a fan of this type is shown in Fig. 2A.

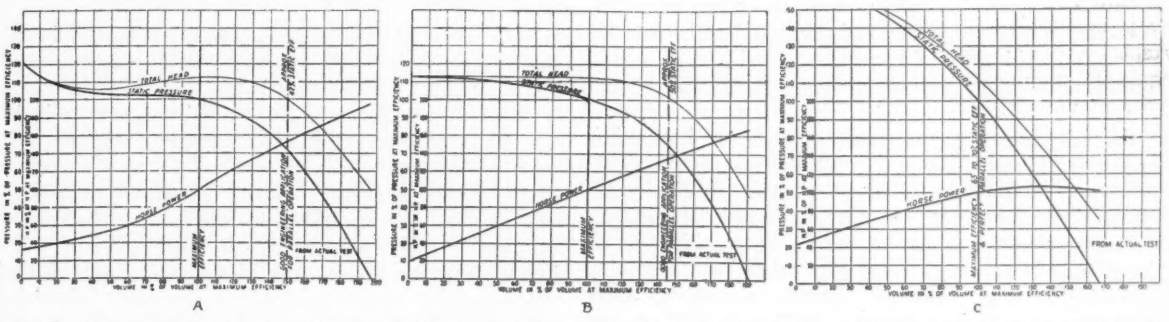


FIG. 2. CHARACTERISTICS OF FANS WITH DIFFERENT TYPES OF BLADING. A, FORWARD CURVE BLADING. B, RADIAL TIP BLADING. C, FULL BACKWARD CURVE BLADING

Radial tip fans have their blades curved tangent at the periphery to a radius of the wheel as shown in Fig. 3. In this fan the tendency is to maintain the pressure constant and if well designed will give a total head practically flat to the point of extreme velocities.

Partially backward curved blade fans have practically the same characteristic as steel plate fans. The pressure curve tends to fall continually with volume,

although in the more efficient types there is a slight rise at low volumes.

In the full backward curve fan the blade curvature is carried back to a much greater degree. The pressure curve is sloped more than with any other type, and the horsepower curve instead of being a straight line is a convex curve. This type of fan is admirably suited to forced draft work. It has a higher speed than any of the others mentioned and its efficiency is inherently high because a large part of the energy is already

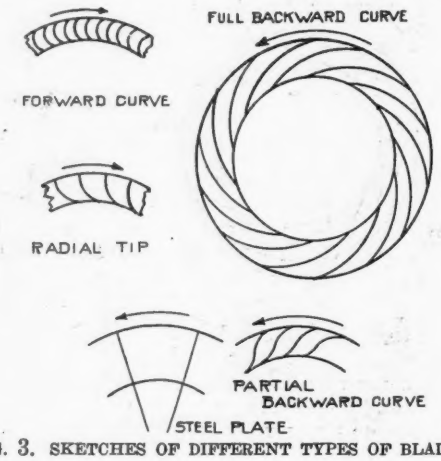


FIG. 3. SKETCHES OF DIFFERENT TYPES OF BLADING

static pressure when the air leaves the impeller. These fans have ample reserve capacity and can be successfully operated in parallel.

Pressure Systems

Forced draft pressure systems are of two kinds, those in which each fan is connected to its individual boiler by a separate duct and those in which a number of fans are connected into a common system of ducts, supplying air to one or more boilers. Practice in this respect is divided. Boiler units of 800 hp. and larger, equipped with forced draft stokers, are suitably served by individual fans.

Practice in regard to forced draft systems has undergone a considerable change in recent years, particularly insofar as draft pressures are concerned. With the advent of underfeed stokers developing high boiler ratings, it became necessary, due to the increased thickness of the fuel beds and high rates of combustion, to employ much higher draft pressures than were formerly used.

Older types of fans were not built sufficiently heavy for operation at high speeds necessary to produce the high pressures demanded, consequently new types were developed capable of being operated at high speeds. The method of driving also changed from the use of the slow speed reciprocating engine to high speed turbines and electric motors. Of course, the slow speed fan is not limited to slow speed drives; for by means of suitable reduction gears any type of drive may be used.

To select a fan of proper size to meet the required conditions is a matter which is most suitably accomplished through the use of capacity tables furnished by manufacturers. Knowing the outlet velocity of the air in feet per minute and the static pressure, these tables will give the correct size of any fan in horsepower capacity. The nearest commercial size which will meet the volume and static pressure requirements should be selected.

Method of Driving and Control

Proper selection of a fan drive depends largely upon local conditions. Where exhaust steam from auxiliaries can be used to advantage, turbine driven units are perhaps to be preferred, or in cases where it is desired to maintain an economical heat balance it is sometimes desirable to install some steam-driven units and some electrically-driven units. Another thing that must be taken into account in the selection of drive for fans is the nature of the boiler plant load. If, for instance, the entire steam supply is used for electric generating purposes, a failure on the electrical system will automatically cut the load off the boilers. In such cases electric drives can be used throughout. If, on the other hand, a considerable part of the steam produced is used in factories for process work, and if electric

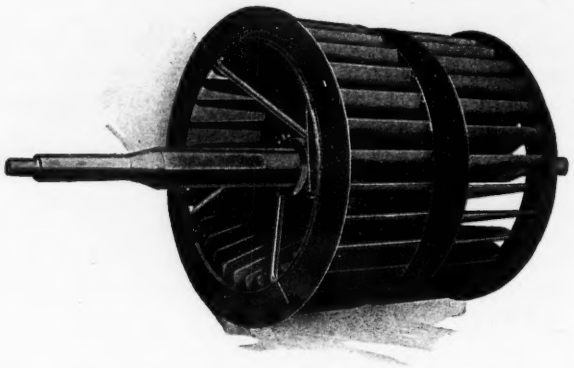


FIG. 4. BLAST WHEEL OF MULTI-BLADE STOKER FAN SHOWN IN FIG. 1

motors were installed to drive the stoker fans, it is obvious that an interruption on the electrical system would seriously affect boiler operation.

Modern practice in electric driving seems to incline towards the use of induction motors of the slip ring type, although in some cases direct current motors are used. Hand control is usually employed in the case of motor fan drives. With the engine or turbine driven installation automatic control is more common. This has usually taken the form of a chronometer valve in the steam line to the fan turbine, the valve being operated by a damper regulator and varying the speed of the fan in accordance with the steam pressure.

In Fig. 5 is shown a typical example of a modern forced draft installation. All fans, it will be noted, connect into a common system of ducts.

Exhausters

Requirements to be met by induced draft fans or exhausters differ materially from the requirements of forced draft practice. The conditions under which such fans are required to operate are much more severe than the conditions imposed by forced draft systems, and to decide upon a satisfactory induced draft system necessitates considerable experience and common sense.

Induced draft has a number of advantages over forced draft but, except in the case of small installa-

tions having stokers with only a small draft loss through the grates, should not be used alone, otherwise the fan capacity becomes large and the installation expensive. Between the two systems, forced draft and induced draft, an induced draft system costs considerably more than a forced draft system on account of the larger fan required. The most suitable arrangement is a combination system in which the forced draft fan overcomes the resistance through the fuel bed while the induced draft fan is called upon only to overcome the resistance

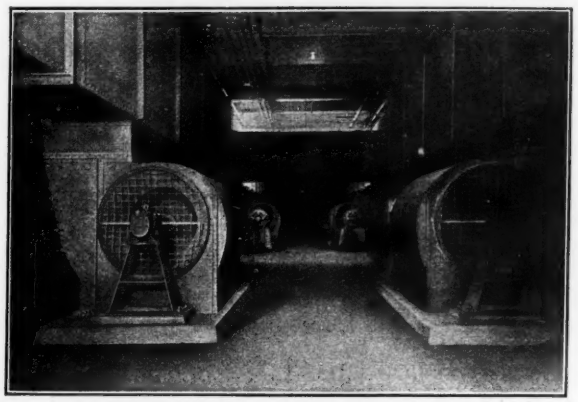


FIG. 5. FORCED DRAFT INSTALLATION AT ASHLEY ST. STATION, UNION ELECTRIC LIGHT & POWER CO.

to the flow of gases through the boiler and economizer and further to furnish a slight draft in the fire box.

Type of Construction

Since the induced draft fan handles hot gases it must be capable of handling a much larger volume of gas than the forced draft fan. For usual installations the hot gases at the induced draft fan have a density of only half of the air at the forced draft fan, consequently their volume is twice as great. To deliver this will, of course, require twice the horsepower.

Induced draft fans have usually been of the narrow multi-bladed type, this being necessitated by the speeds at which they run, most installations being direct connected to the driving motor. The use of fans of this type, however, involves certain difficulties due to the space between the blades clogging up. Without question the steel plate or paddle wheel type of fan of proper proportions is by far the most suitable of all for this work.

Special Construction for Hot Gases

In order to obviate bearing troubles and to provide an unobstructed inlet passage, most fans for induced draft work are of the overhung type, that is, both bearings are on one side of the fan, and outside of the flow of hot gases. Water-cooled bearings are sometimes provided to eliminate overheating caused by heat of the gases, being conducted along the shaft to the bearings.

What has been said in regard to method of drive for forced draft fans applies more or less to induced draft fans. Whether steam or electric drive is to be used depends upon existing local conditions. Alternating-current motors of the wound-rotor induction type, hand operated and direct connected to the fans, seem to be the preferred method of drive at the present time.

Measurement of Air Flow

Methods of Determining Amount of Air Passing in Forced Draft Installations

THERE ARE a number of different methods by which the amount of air delivered by a fan may be determined, each of which has certain advantages and disadvantages. It is a comparatively simple matter to test a fan before being installed, with the fan blowing into a long straight duct, but to test it after installation in the power plant is more difficult. In the latter case the double pitot tube is the most convenient method to use.

A simple, although not highly accurate, method for measuring directly the volume of air in a passage is by the use of an anemometer. This is an instrument for measuring air velocity and as may be noted from Fig. 1 generally consists of a wheel with vanes against

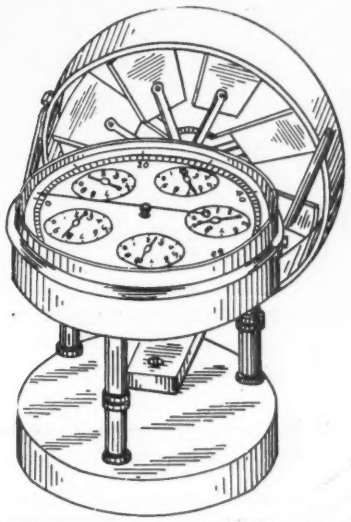


FIG. 1. ANEMOMETER FOR MEASURING AIR VELOCITY

which the current of gas impacts, causing a rotary motion proportional to the velocity of the current. This motion is transmitted to a gear and counter combination which registers linear feet continuously. By counting the time the velocity in feet per second or minute may be calculated.

In using this instrument to measure the volume of air delivered by a fan, it is generally placed at the exit cross section of the duct. In order to obtain the average velocity of the air, the cross-section of the duct may be divided into a number of small areas and a reading taken in each. The average velocity thus obtained may be used with which to multiply the area of the duct in order to arrive at the number of cubic feet of air delivered per minute or per second.

As stated above, the foregoing method is not accurate since it may involve errors of from 5 to 30 per cent. The percentage of error is not constant and varies considerably with the diameter of the pipes and the speed of the air. The results obtained by this method should be considered only as rough approximations.

Double Pitot Tube Method

What is known as the double pitot tube furnishes a method of testing fans by which an accuracy of within

2 per cent can often be attained. The double pitot tube is a device constructed as shown in Fig. 2. It is made of two brass tubes, the outer one ¼ in. and the inner one ⅛ in. external diameter, each about 4 or 5 in. long, the two being soldered together at one end and the end then tapered down to a sharp edged nozzle. The outer tube has two or more smooth holes drilled in it, diametrically opposite and at right angles to the axis to receive the static pressure. Each tube may be connected to a manometer, one reading the total or dynamic pressure and the other (the outer tube) the static pressure. The velocity head can then be obtained by taking the difference between the readings of the manometers. If desired, however, the two tubes may be connected to a single manometer and the velocity head read off directly.

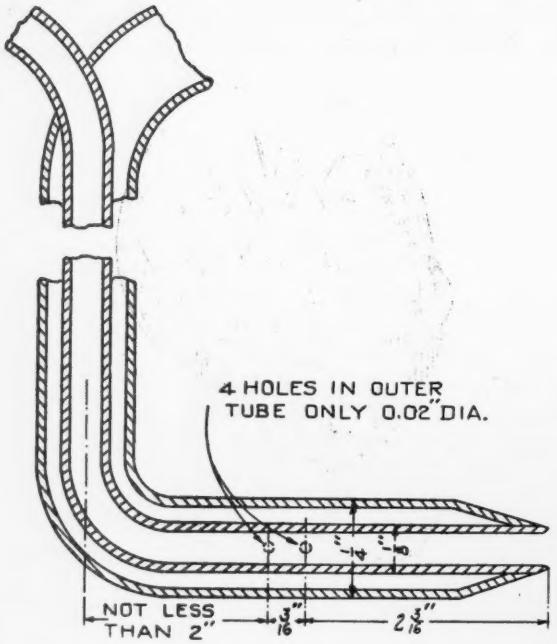


FIG. 2. DOUBLE PITOT TUBE

The velocity of the air in the duct can then be calculated from the velocity pressure by means of the following formula:

$$V = 1096.2 \sqrt{P \div W}$$

where V = velocity, ft. per min.
P = velocity pressure in inches of water
W = density of air in lb. per cu. ft.

The average weight of a cubic foot of air was found by the American Blower Co. in a large number of tests to be 0.0715 lb. Using this value for W in the above formula, it becomes

$$V = 4101 \sqrt{P}$$

Knowing the velocity of the air, the volume in ft. per min. can be obtained by multiplying by the area of the duct.

Another method of determining the amount of air delivered by a fan is by means of the capacity tables furnished by manufacturers. If the size of the fan is known, the amount of air delivered at any speed and under varying conditions of static pressure may be readily determined.

Fuel Determination

By Scales, Meters and Counters for Coal. By Meters for Oil

SYSTEMS EMPLOYED for the measurement of fuel, particularly coal, depend to a large extent upon local conditions. The size of the plant, the quantity of fuel used, the type of fuel, the method of delivery and storage and the method of firing are some of the

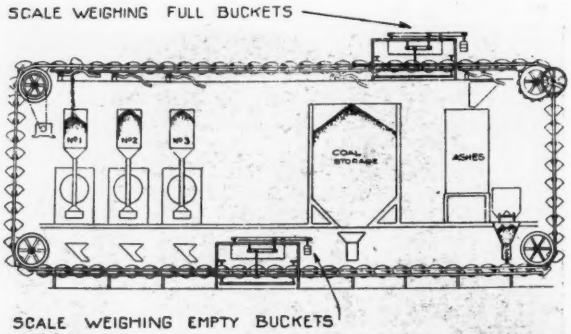


FIG. 1. DUPLEX SCALE APPLIED TO PIVOTAL BUCKET CARRIER

factors which determine the system of coal measurement at any plant. Weighing equipment is conveniently divided into three classes, that for weighing the coal as received, that for weighing the coal as it is consumed by each boiler unit and that for weighing or measuring the total amount of coal consumed.

Coal deliveries are as a rule weighed on receipt while a record is also kept of the total daily consumption.

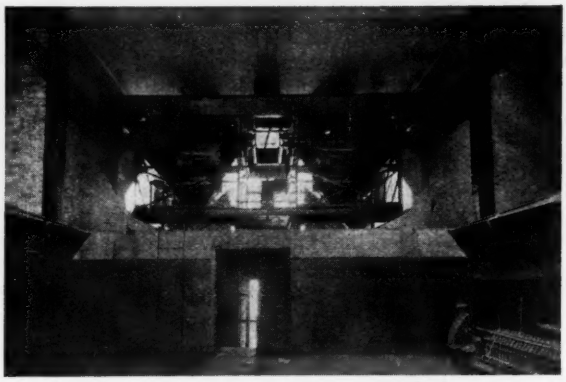


FIG. 2. TYPICAL WEIGH LARRY

These two weighings or measurements will furnish a basis for calculating the reserve stocks.

Wagon scales, track scales, weighing hoppers, coal meters and conveyor weighers are usually used for checking deliveries while for determining the amount used each day, in adition to the foregoing devices, there is also available the traveling weigh larry.

Conveyor weighers are used to weigh coal while in motion on conveyors and operate continuously while the fuel is being handled. A typical weigher of this type as applied to a pivoted bucket conveyor is depicted diagrammatically in Fig. 1. In this case, two scale beams are made to work against each other, one for the gross weight and the other for the tare. The difference between the loaded and unloaded part of the conveyor

is registered, which of course is the true net weight of the coal delivered by the conveyor.

Automatic coal scales are usually arranged with a weigh hopper into which coal is fed until it contains a certain definite amount, say 400 or 500 lb. At the instant when the hopper is filled, the feed is automatically shut off and a gate at the bottom of the hopper is opened allowing the contents to discharge, provided there is space enough underneath. The bottom gate is then automatically closed and the feed again started. Each load is recorded by a counter so that the number of loads which have passed through the hopper can be read at any time.

Weigh Larries

In Fig. 2 is illustrated a typical weighing larry. These are usually used to take coal from the overhead coal bunkers in the boiler room and deliver to the various

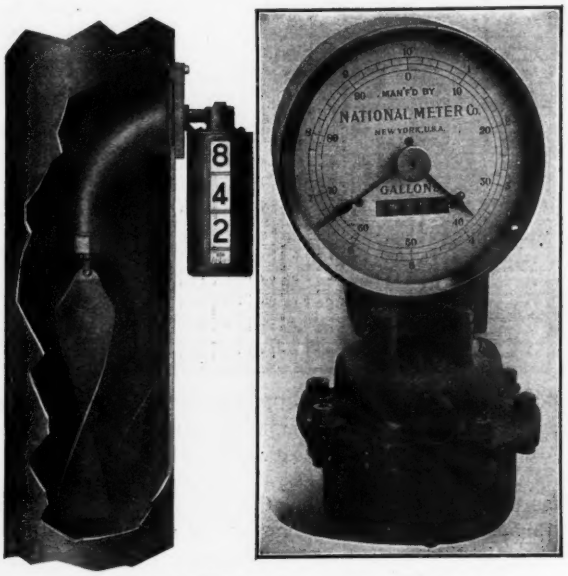


FIG. 3. COAL METER FOR USE IN GRAVITY SPOUT
FIG. 5. FUEL OIL METER

stoker hoppers. Larries of this type are suspended from overhead tracks and are moved either by hand or power. In the machine shown in the illustration, the operator stands on the platform and is carried along on the machine. In others, the operation is effected by means of a controller with two ropes hanging within reaching distance of the floor. These larries are equipped with scales either hand operated or automatic, as desired.

Coal Meters

There is another type of device in use for the measurement of coal, generally known as a coal meter. An instrument of this kind is shown in Fig. 3. It is usually inserted in a gravity spout and is calibrated empirically for different grades and sizes of coal. As may be noted, it is operated by a vane projecting into the center of the pipe through which the coal passes. The movement of the coal causes the vane to turn a definite amount with each foot of coal travel. This motion is transferred through the flexible shaft to the counter.

Coal consumption may also be measured by means of a counter on the stoker and by measuring the fuel bed thickness in the case of chain grate stokers. The coal meter shown in Fig. 4 operates on the former principle and is nothing more nor less than a counter which may be attached to the stoker crankshaft or to the Cole Automatic on Jones stokers. The number of strokes registered multiplied by a constant gives the

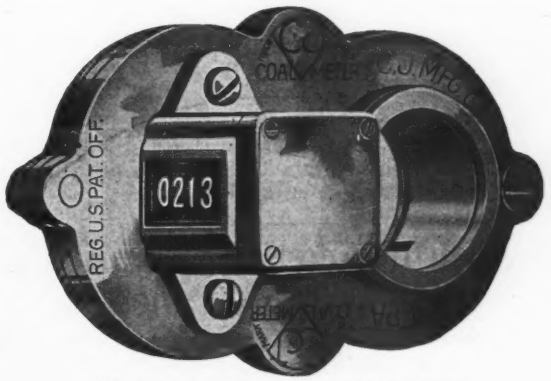


FIG. 4. COUNTER TYPE OF COAL METER

total amount of coal used in tons or pounds, depending upon the constant used.

Fuel Oil Meters

In any installation where oil is used as fuel, means must be provided whereby the quantity used may be accurately determined. While this may be done by taking periodic tank measurements, it is probably much more satisfactory to install a suitable fuel oil meter.

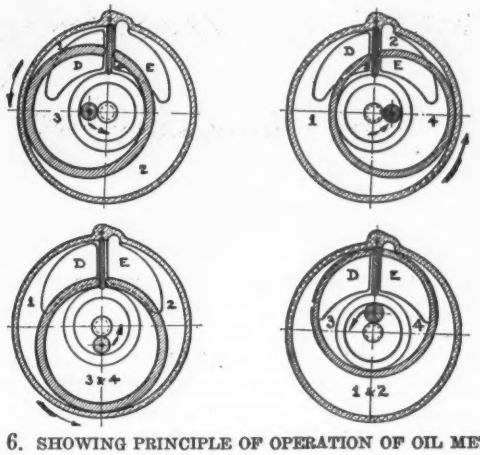


FIG. 6. SHOWING PRINCIPLE OF OPERATION OF OIL METER

There are a number of meters upon the market which differ more or less in design and construction, but most of which are reliable. The positive displacement machine of the piston type or an oscillating piston type is to be preferred, however, because of its extreme accuracy.

These meters are usually placed in series with the line through which the oil is being delivered. The oil flowing through the meter actuates a piston, the motion of which is transmitted to a counter or dial mechanism.

In Fig. 5 is shown a typical fuel oil meter. This is a meter of the positive displacement, oscillating piston type. Its mechanical features and principle of operation is shown in Fig. 6, A, B, C and D.

In A, Fig. 6, spaces 1 and 3 are receiving liquid from inlet port D, and spaces 2 and 4 are discharging through the outlet port E. In B, the piston has advanced and space 1 in connection with the inlet port has enlarged and space 2 in connection with the outlet port has decreased while spaces 3 and 4 which have combined are about to move into positions to discharge through the outlet port.

At C, space 1 is still admitting liquid and space 3 is just opening up again to the inlet port, where spaces 2 and 4 are discharging through the outlet port.

D, shows liquid being received into space 3 and discharged from space 4 while spaces 1 and 2 have combined and are about to begin discharging as piston moves forward again to occupy position shown in A.

Clean Furnace Surfaces Are of Great Importance

Reduction in Heat Transmission Efficiency Means Large Loss if Not Corrected

SOOT, furnace scale and dead gas film are deadly enemies of effective heat transmission and must, therefore, be taken into consideration if the most economical operating conditions are to be maintained. An increase of boiler efficiency of from 2 to 10 per cent may be effected by proper removal of soot accumulation,

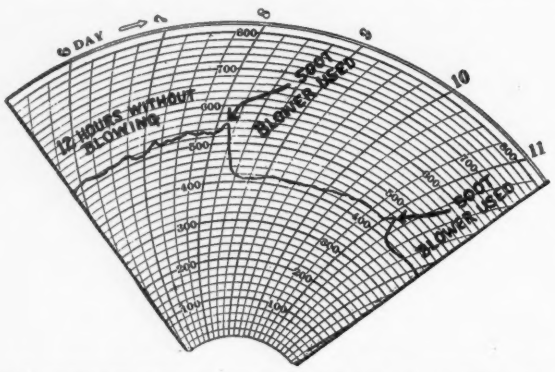


FIG. 1. TYPICAL CASE OF REDUCTION OF FLUE GAS TEMPERATURES DUE TO SOOT BLOWING

removal of slag from lower tube banks and changes in baffling to give proper gas velocities and elimination of inert spaces.

That this subject has a real dollars and cents value in plant operation may be shown from an example which is not unusual in any respect. In Fig. 1 is shown the flue gas temperatures in a plant where soot blowing equipment was installed. It will be noted that after 12 hr. of operation without blowing the temperature rose to 545 deg. F. and that after blowing the temperature dropped to 405 deg. F. or a difference of 140 deg. F.

It is quite customary to figure that for each 20 deg. F. reduction in the temperature of the flue gases there is an increase of 1 per cent in the boiler efficiency. In this case, the increase would be 7 per cent.

Assuming that the boiler plant was operating at 65 per cent efficiency before the blowing and using coal of 13,000 B.t.u. it can be seen from Fig. 2 that the rate of combustion would be 3.9 lb. per hp.-hr. By increasing the efficiency 7 per cent or to 72 per cent, the combustion rate would be reduced to 3.5 lb. per hp.-hr., which would mean a coal saving of 0.4 lb. per hp.-hr. If a 250-hp. boiler were operated 10 hr. a day, the saving would be 1000 lb. of coal a day. The total coal burned would be 8750 lb., so the saving would amount to 11 per cent. The preventive measure is to keep the surfaces clean, the type of cleaning equipment and the length of time between cleanings depending on operating conditions.

Soot and slag collect at a rate which depends on a number of factors such as, the kind of fuel used, the methods of firing, control of draft, the thickness of the fuel bed, the size of combustion space, the length of

B.T.U. per lb. coal.	50% Efficiency.		55% Efficiency		60% Efficiency		65% Efficiency		70% Efficiency		75% Efficiency		80% Efficiency	
	Evaporation per lb. coal.	Lbs. coal per hp. hour.	Evaporation per lb. coal.	Lbs. coal per hour.	Evaporation per lb. coal.	Lbs. coal per hour.	Evaporation per lb. coal.	Lbs. coal per hour.	Evaporation per lb. coal.	Lbs. coal per hour.	Evaporation per lb. coal.	Lbs. coal per hour.	Evaporation per lb. coal.	Lbs. coal per hr. hour.
7500	3.8	9.0	4.2	8.2	4.6	7.5	5.0	6.8	5.4	6.4	5.8	6.0	6.2	5.5
8000	4.1	8.4	4.5	7.6	4.9	7.0	5.3	6.5	5.7	6.0	6.2	5.5	6.6	5.2
8500	4.4	7.8	4.8	7.1	5.2	6.6	5.7	6.0	6.1	5.6	6.6	5.2	7.0	4.9
9000	4.6	7.5	5.1	6.7	5.5	6.2	6.1	5.5	6.5	5.3	6.9	5.0	7.4	4.6
9500	4.9	7.0	5.4	6.3	5.9	5.8	6.3	5.4	6.8	5.0	7.3	4.7	7.8	4.4
10000	5.1	6.7	5.6	6.1	6.2	5.5	6.7	5.1	7.2	4.7	7.7	4.4	8.2	4.2
10500	5.4	6.3	5.9	5.8	6.5	5.3	7.1	4.8	7.6	4.5	8.1	4.2	8.6	4.0
11000	5.6	6.1	6.2	5.5	6.8	5.0	7.4	4.6	7.9	4.3	8.5	4.0	9.1	3.7
11500	5.9	5.8	6.5	5.3	7.1	4.8	7.7	4.4	8.3	4.1	8.9	3.8	9.5	3.6
12000	6.2	5.5	6.8	5.0	7.4	4.6	8.0	4.3	8.6	4.0	9.3	3.7	9.9	3.4
12500	6.4	5.3	7.1	4.8	7.7	4.4	8.4	4.1	9.0	3.8	9.7	3.5	10.3	3.3
13000	6.7	5.1	7.4	4.6	8.0	4.3	8.7	3.9	9.4	3.6	10.0	3.4	10.7	3.2
13500	6.9	5.0	7.6	4.5	8.3	4.1	9.0	3.8	9.7	3.5	10.4	3.3	11.1	3.1
14000	7.2	4.7	7.9	4.3	8.6	4.0	9.4	3.6	10.1	3.4	10.8	3.2	11.5	3.0
14500	7.5	4.6	8.2	4.2	9.0	3.8	9.7	3.5	10.5	3.2	11.2	3.0	12.0	2.8

FIG. 2. RATE OF COAL CONSUMPTION FOR VARYING BOILER EFFICIENCIES AND GRADES OF COAL, BASED ON EVAPORATION FROM AND AT 212 DEG. F.

gas passage before striking the boiler surfaces, and the system of baffling. Inert gas spaces are usually due to a particular method of baffling and the gas velocity through the different passages.

In the case of low boiler settings, long flaming fuel with tarry constituents, or horizontal systems of baffling, the use of mechanical soot blowing methods appears to be especially desirable. As the size and the height of the combustion chambers in modern boiler settings are increased, however, allowing complete combustion of the fuel to take place before the gases strike any part of the relatively colder boiler surfaces, the necessity for soot blowing is reduced, but not eliminated.

As pointed out in the 1922 report of the Prime Movers Committee of the National Electric Light Association very definite results may be expected to follow proper attention to surface cleanliness. In one case cited, a 650-hp. vertically baffled water-tube boiler was operated at 150 per cent rating for a period of 14 days without blowing the tubes. As a result, the flue gas temperature increased 45 deg. F.

Another case cited a plant having 1300-hp. boilers which was allowed to operate for five weeks without blowing the tubes. Careful tests at the end of this time showed a reduced boiler efficiency of 7.5 per cent at 240 per cent rating.

Accumulation of slag on the lower tube banks is a source of operating trouble which occurs frequently.

The condition may become so bad that the working area of the first passage may be reduced to a point which will affect the boiler rating. In such cases, it is necessary to remove the boiler from service for a thorough cleaning. Careful daily attention may reduce such troubles, as in many types of boilers it is possible to reach the lower tube banks and to clean the tubes with a bar scraper.

While the character of the fuel may be the cause of such slag accumulations, it is also intensified by high gas velocities which carry fine particles from the fuel bed and deposit them on the tubes, where final combustion takes place. The remedy lies either in a change of the fuel characteristics or a reduction of the gas velocity. Frequently it is possible to change the baffling to give a wider through area which in turn reduces the gas velocity over the fuel bed but at the same time does not reduce the effective draft.

An inert gas film in contact with any section of the tubes also reduces the ability of hot gases to transfer their heat to the water. To all practical purposes, the actual heating surface of the boiler is reduced by such dead pockets. Recently the practice in baffling has taken this point into account and by narrowing the passage at the point of turn into the next passage, all corners are swept clear by the higher velocity.

Although not a material substance, the handling of dead gas pockets should be looked upon much the same as soot, slag or scale for the effect on heat transfer is somewhat similar. Draft readings should be taken to check up on the velocity in the corners of the various passages.

Heating Surfaces Should Be Cleaned Systematically

WHEN IT HAS been fully realized just how important it is to have clean heat transmitting surfaces at least a part of the battle for higher operating efficiencies has been won. This in itself is not sufficient, however, for even with the very latest and best types of cleaning equipment, it is important that the work be performed on some definitely scheduled basis which has been worked out according to existing conditions.

Soot should be blown at least every 24 hr., and in most plants it is customary to blow at least once during each 8 hr. shift. When the boilers are being forced at a high rating, it is necessary to blow more frequently. Some fuels are also worse than others in the amount of soot deposited, hence no definite rules can be laid down for the frequency of blowing. It is a matter which must be worked out individually.

Soot May Bake on Tubes

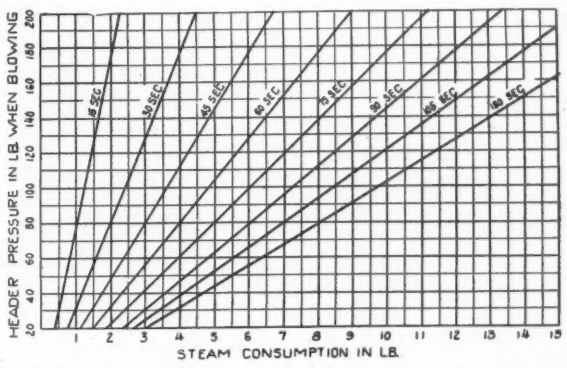
If soot is allowed to accumulate for periods longer than 24 hr., it has been found that the fixed blower will not entirely remove the deposits. The time between cleanings should take this point into account, as one of the principal arguments for permanent blowers is that the boiler will not have to be taken off the line as often for a periodical cleaning. If the time between blowings is too long, it will be necessary to take the boiler out of service in order that the tubes may be scraped.

It is usually customary to blow the soot a short time before the boiler will be called on to meet a peak load. In small plants, it is frequently the custom to clean the fires just before the peak comes on and it is good practice to use the blowers just after this.

After a blowing schedule has been determined, it is important that the work be properly performed. This is true not only when the blowing is done with a hand lance, but also where it is done with fixed blowers. As soot is removed by the direct impact of the jet, it is quite evident if the jet is rotated too rapidly, thorough cleaning will not take place. On the other hand, if the operation proceeds too slowly more steam will be used than needed.

Steam May Be Wasted in Soot Blowing

Few operators have any conception as to the steam consumption of soot blowing equipment and the value of correct operation should be impressed on them. In Fig. 1 is shown the amount of steam passing through



STEAM CONSUMPTION FOR A 5/16-IN. JET WITH VARYING HEADER PRESSURES AND DIFFERENT LENGTHS OF TIME

a single 5/16-in. jet for varying lengths of time and under different header pressures. It is quite easy to approximate the steam consumption for the soot blowing operation. For instance, with a 100 lb. header pressure, 2.4 lb. of steam will flow through a nozzle if the valve is open 30 sec. while 9.6 lb. will be used if the valve is left open 120 sec.

In other words, a standard 21 tube wide vertically baffled boiler with five units of 20 jets each, or 100 jets, would require 240 lb. of steam in 30 sec. If the blowers were each left on 120 sec., the steam consumption would be 960 lb. Therefore the loss would be 720 lb. or 2160 lb. every 24 hr. if the boiler were blown three times a day. With the boiler in service 300 days a year this would amount to a total of 648,000 lb. With coal at $5 a ton it costs 31 cents to evaporate 1000 lb. of water from and at 212 deg. F., assuming an evaporation of 8 lb. of water per lb. of coal. In other words, the fuel cost would be about $200 per year. If the operator is even more careless and with a number of boilers in use, it can be seen that this source of loss may be one that really amounts to something.

Assuming that a schedule of soot blowing has been laid out and the operators properly instructed as to operation, the next point for consideration should be as to how frequently a furnace and boiler should be thoroughly cleaned by taking it out of service and going over all parts with scrapers, brushes and the steam lance. The frequency of such a cleaning depends on local con-

ditions such as how hard the boiler is being forced, the kind of coal used, type of baffling, gas velocity, etc.

Slag accumulations on the lower tube bank determine the time of cleaning about as closely as any other one item. Usually in four or six weeks the boiler needs such a cleaning even if regular soot blowing also takes place.

Entire Boiler Should Be Cleaned

If there are spare boilers in the plant each one should be taken off the line at regular intervals and given a thorough cleaning. If every boiler in the plant is required for the daily load the work of cleaning must be done on Sundays and holidays. In such cases the fire under the boiler should be burned out as early as possible on the previous day. Dampers and fire doors should be left open so that air may circulate and cool the setting. At least 6 hr. should be allowed for cooling before emptying the boiler.

If the feed water conditions are good and not much scale is formed it may not be necessary to turbine the tubes or clean the headers internally at the time the combustion chamber and external tube surfaces are cleaned. This is, however, a matter for local decision and in this discussion it will be assumed that the entire boiler is to be given a thorough cleaning.

While the boiler is cooling off, the ashes may be cleaned out of the combustion chamber and back connection. Also, a staging may be erected in front for work on headers and tubes and the tube cleaners, hose, and pump or compressor prepared for work. As soon as the boiler is emptied, the front caps may be removed, manholes opened and drums washed out. Several men equipped with chisels, scaling hammers, etc., may enter the drums and begin the work of removing scale. As soon as caps are off, the tube cleaner should be started. Caps, nuts, bolts and binders should also be cleaned. Headers should be cleaned by chipping the scale deposits off with chisels and scaling hammers. The entire boiler should then be thoroughly washed out.

External surfaces of the tubes, headers and drums should also be cleaned. As a rule, the tubes must be scraped to clean off the slag accumulations after which a thorough blowing with a steam or air lance will remove the balance of the accumulations. Another method used in some plants is to wash off the tubes, after scraping, with water from a hose. Care should be taken to use no water until the setting is cool and it is better to use the hose while the tubes are full of water, as there is less danger of causing undue contraction.

Baffles and the combustion chamber should also be thoroughly cleaned. Sometimes the baffle walls are scraped, in which case care should be used not to up-end any of the baffle tile when the wall is of this type of construction.

Types and Arrangement of Soot Blowers

Method of Overcoming Effect of High Temperatures and Prevention of Too Rapid Operation. How Elements Are Applied to Various Boilers

Soot blowers are divided into two general classes; the blower of the portable hand operated type, such as the steam lance, and the permanently fixed types which are operated by means of chains or levers. In the case of either of these types there is also a further subdivision depending on whether the boiler is of the water tube or fire tube type.

Blowers of the hand type have been extensively used in the past but with the increasing size of boiler settings and the consequent difficulty of reaching all parts of the working surface, without taking the boiler out of service, the fixed types have come into more general use.

It is probable that in small plants the hand blowing equipment will continue to be used unless economic considerations warrant the installation of fixed blowers. Even where permanently installed cleaners are in use, however, many companies continue to use the hand lance for cleaning at times when the boiler is taken out of service for a complete overhauling.

Development of fixed blowers has not been a problem easy of solution on account of the severity of the operating conditions. It has been necessary to design the blowing elements with regard to the high temperatures encountered, proper placement in the boiler to insure the cleaning of all parts of the surface, and the development of an operating mechanism that would conserve steam and yet not allow such a rapid action as to slight the work.

Probably the most attention has been given to the effect of high temperatures on the blowing elements. Air cooled, heat treated and sheathed elements, and of late the use of special high temperature alloys, are some of the methods which have been adopted to solve this problem. As a result, such apparatus has now reached a point where a reasonably long life may be expected of fixed soot blowers even though operated under high temperatures.

In Fig. 1 are shown the construction details of a blower unit which has been designed with a view of overcoming some of these operating difficulties. The blower nozzles in this type are made of monel metal, while the steam tube is protected by means of an outer air tube which is built in sections to prevent warping. For usual temperature conditions, the outer casing is made of charcoal iron but if unusual conditions are to be met, the tube is made of monel metal. A continuous flow of air is circulated in the space between the steam element and the air tube.

Elements of a special nickel base alloy combined with such elements as molybdenum, titanium and zirconium are used by another manufacturer. In the case of these metals the castings are poured at a temperature of 3500 deg. F. Still another manufacturer has had successful experience with a blowing element which has been heat treated by a process known as calorizing. Electric spot welding of the nozzles has also been used with success.

One difficulty experienced in obtaining thorough cleaning is due to the rapidity with which the operators rotate the nozzles. If the soot is inclined to adhere closely to the tubes the force of the steam jet, when passed rapidly by the tube, is not sufficient to blow off the deposit.

In the soot cleaner shown in Fig. 2, a sprocket head which can be rotated only one step at a time after which the opposite chain must be pulled to release the ratchet before the next step can be taken has been developed to meet this condition. In this way, the operator is forced to take a certain amount of time to complete one revolution of the blower.

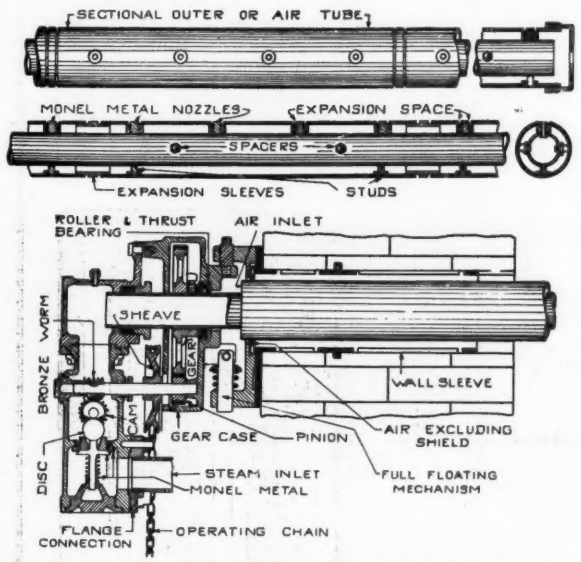


FIG. 1. VALVE-IN-HEAD BLOWER WITH AIR COOLING AND SECTIONAL OUTER SHEATH

FIG. 2. RATCHET HEAD TYPE OF BLOWER WHICH CAN ONLY BE ADVANCED ONE STEP AT A TIME

In the head shown in Fig. 1, this function is taken care of by the use of a reduction gear. Although the chain may be pulled quite rapidly, the nozzles revolve at a speed slow enough for effective operation. The blower shown in Fig. 3 uses the same general method. In another design this same object is accomplished by making the reduction in speed between the hand wheel and the blower head wheel.

Nozzle design has been given much attention both for the blowers used in water tube boilers and those used for cleaning boilers of the fire tube type. Even more important, however, is the location of the units in order to secure the maximum effectiveness. As shown in Fig. 4, there are many arrangements possible depending on the type of boiler, method of baffling and the particular operating conditions to be met.

Two general methods of equipping Babcock & Wilcox boilers with soot blowers are shown in Figs. 4A and 4B. In the first case, two blowers are placed at the top of the tube bank in the first pass although as shown in the second case a third element is sometimes added as indicated by K. As temperature conditions are the highest in the first pass, it is customary to furnish units of special alloy or sheathed as previously mentioned. The unit at K is not usually necessary except in cases

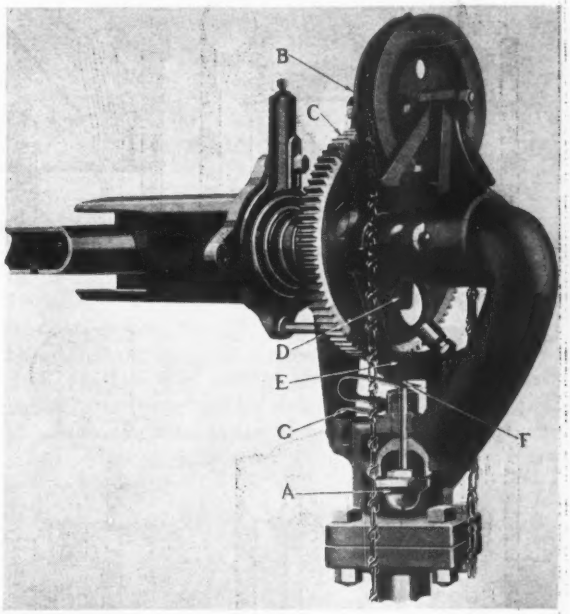


FIG. 3. VALVE-IN-HEAD BLOWER IN WHICH A IS LOCATION OF VALVE IN GOOSE NECK; B, SHEAVE WHEEL; C, GEAR; D, CAM; E, LEVER; F, VALVE STEM; G, SPRING

where an unusual amount of soot is deposited. In Fig. 4B it will be noticed that one unit has been dispensed with as unit No. 4 is placed directly under the second baffle, hence sweeps both the second and third pass.

Where a superheater is installed it is considered advisable to install a unit just above the heater so that it may be swept clear of deposits. Frequently the same general arrangement is used in boilers of the Edge Moor, Keller, Geary and Union types as shown in Fig. 4C.

Stirling boilers offer a problem of somewhat different character as the elements located in the first pass are subjected to unusually high temperatures. As a result, it is customary to build some kind of a protection for units located in this pass. This is taken care of by placing a row of deflecting baffle tile as shown in Fig. 4E. This construction shields the element from radiant heat and also forms a dead gas pocket which is relatively cool. Unit No. 2 is protected by setting the blower in

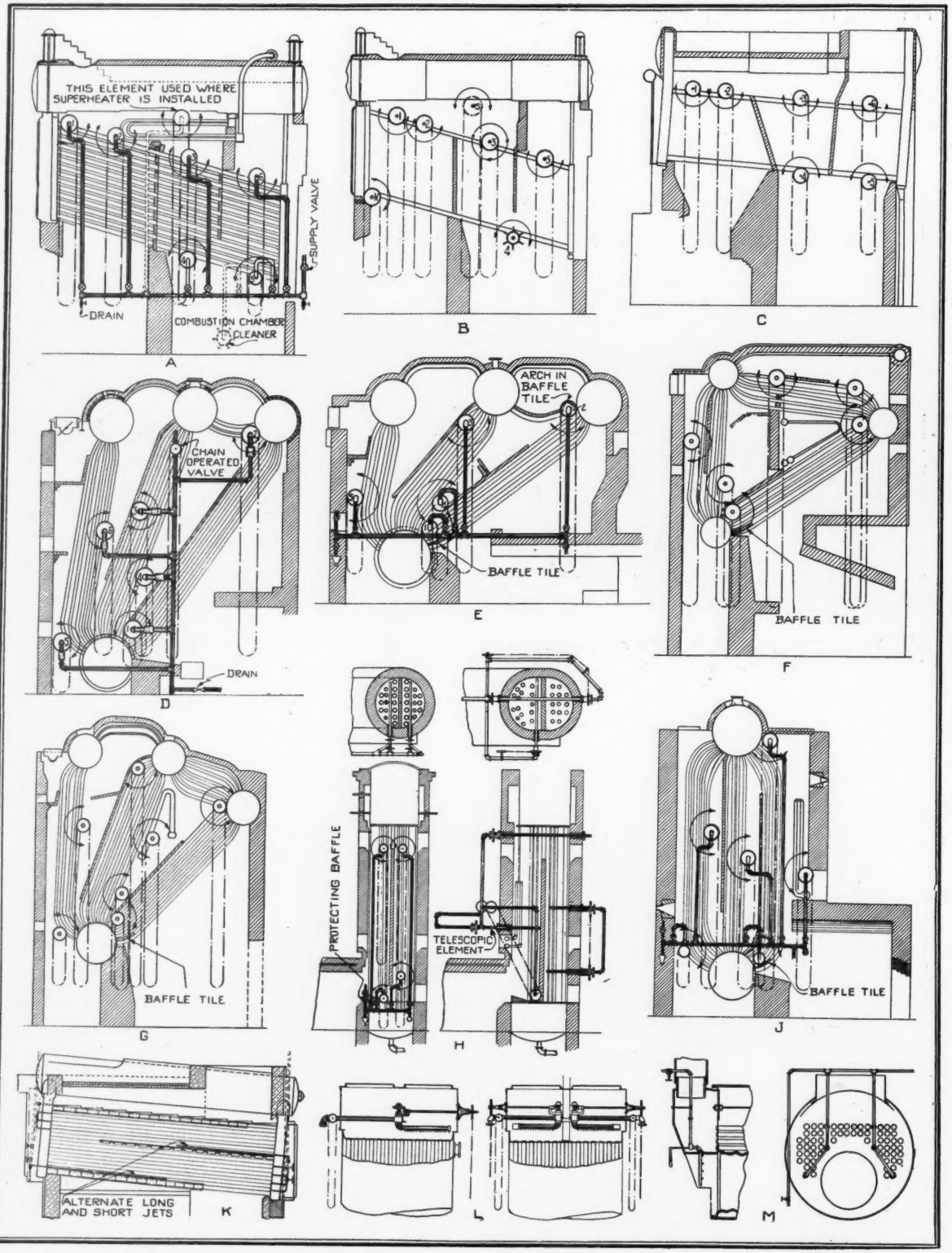


FIG. 4. ARRANGEMENT OF SOOT BLOWER UNITS IMPORTANT FOR BEST OPERATING RESULTS

A.—Babcock & Wilcox boiler showing one method of placing soot cleaning elements. B.—Babcock & Wilcox boiler where a unit is used at bottom of first pass. C.—Edge Moor, Geary, Keeler and Union boilers are sometimes equipped as shown in this layout. D.—Application of a valve-in-head blower installation on Stirling boiler. E.—Location of elements in a low setting Stirling boiler, showing method of protecting units against high temperatures. F.—Typical layout for a Badenhausen boiler. G.—Use of baffle tile to protect element located in first pass of Connelly boiler. H.—Wickes boiler showing how elements are located when there is room at the side. In case the boilers are set in a solid battery, the method on the right is sometimes used. J.—Erie City boiler with protection for units in first pass, the Ladd boiler takes a somewhat similar arrangement. K.—Nozzles brought through hollow staybolts in horizontally baffled Heine water tube boiler. L.—Soot blower installed in a boiler of the Manning type. M.—One arrangement for a Scotch marine boiler.

a pocket made by arching the baffle tile over the circulating tubes. This creates a dead gas pocket which protects the element. As a rule the elements are also sheathed with iron unless a special alloy is used. Figure 4D shows the method of handling a Stirling boiler with a valve in the head installation.

Units No. 1 in the first pass of Badenhausen and Connelly boilers as shown in Fig. 4F and 4G are protected by means of the baffle tile while unit No. 2 is set in close to the drum and is also furnished with extra heavy sheathing or else in a special alloy.

Application of the rotating jet type soot blowers to vertical boilers follows the same general lines as practiced in the horizontal and semi-vertical type boilers.

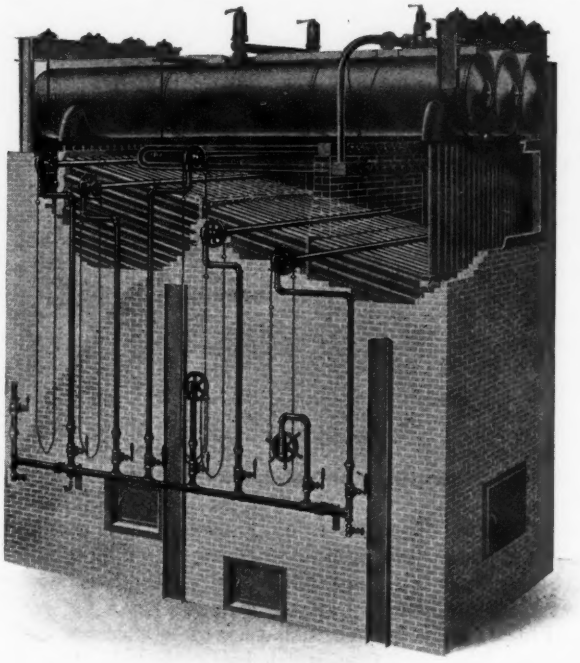


FIG. 5. BLOWER INSTALLATION SHOWING SPECIAL METHOD OF FEEDING THE UNITS

Figures 4H and 4J show how the problem of locating the elements in a Wickes and Erie City have been solved. These particular layouts are indicative of practice but are by no means to be considered as the only arrangement possible. Variations in the vertical boiler design arrangement of boilers and the particular operating conditions must all be taken into consideration before the best positions for the elements can be determined.

Referring to Fig. 4H, it will be noted that an element is located at the bottom of the first pass close to the baffle. While at first glance this might appear to be an exposed location, as a matter of fact its position is practically in a dead gas pocket. Furthermore, the comparatively cold lower drum tends to keep the temperature down. The tubes also offer some protection except at the two ends, where a wedge shaped fire brick construction deflects the gases.

Where boilers are set in solid battery, where a superheater is installed or where special conditions prevail necessitating an element near the middle of the first pass, a telescopic element is sometimes used. The right hand view in Fig. 4H shows the location of such a telescopic unit.

When cleaning has been accomplished, the element is withdrawn from the setting thus being entirely protected from the high temperatures at this point.

FIG. 6. METHOD OF INTRODUCING BLOWER JETS THROUGH HOLLOW STAY BOLTS

For boilers with hollow stay bolts of the Heine type, a layout as shown in Fig. 4K is resorted to. It will be noted that the jets are introduced through the hollow stay bolts. The jets along the horizontal baffles are alternately extended to about the middle of the baffle. This can be seen by referring to Fig. 4K. A detail of the jet arrangement is shown in Fig. 6. In the case of a combination of vertical and horizontal baffling it is necessary to introduce an element which will sweep the tubes from the sides in the pass which cannot be reached by the stay bolt jets. Such a system of jets is shown in Fig. 7.

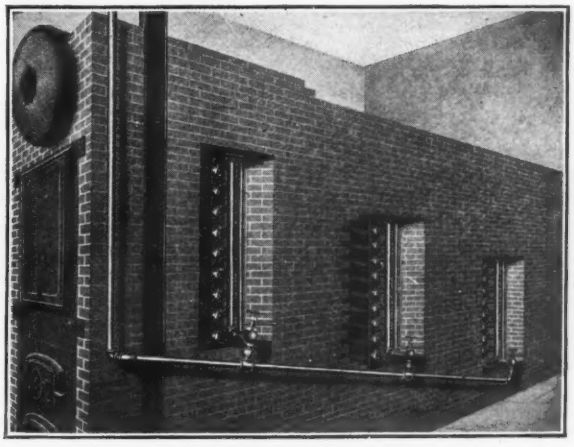


FIG. 7. SIDE JET ARRANGEMENT USED IN CONNECTION WITH THE HOLLOW STAY BOLT METHOD WHERE BOILERS ARE ALSO VERTICALLY BAFFLED

Soot blowers for fire tube boilers are comparatively simple consisting of the steam lance type where each tube is blown singly or the fixed type where all of the tubes on a certain radius line are swept at once. Such

an arrangement is shown in Figs. 4L and 4M for a Manning vertical boiler and a Scotch marine boiler.

Operators installing soot blowers are generally taking greater care in the selection of valves and fittings and in steam piping layout. Best practice now calls for as careful design and as rugged construction in these matters as in other parts of the high pressure system.

Either a vertical or horizontal steam header supplies the branch lines that feed the various units, and it is necessary to provide a main header valve and a valve in each branch line. In the valve-in-the-head type unit supplied by two manufacturers the branch line valves

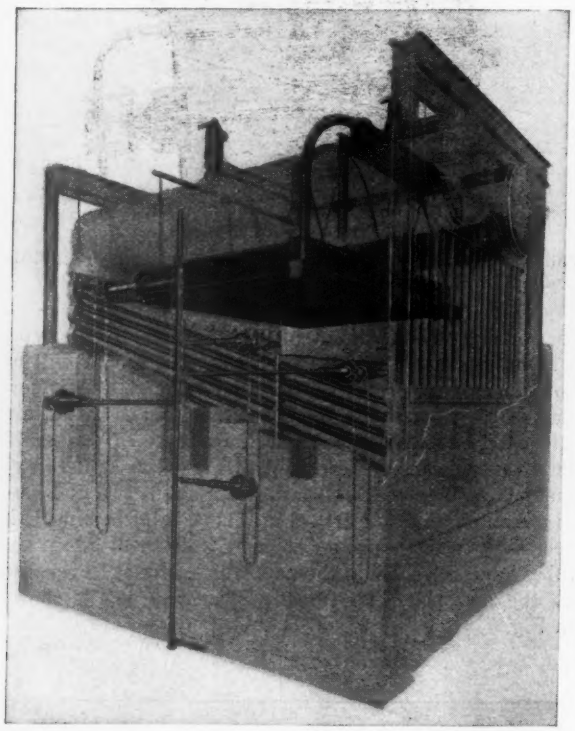


FIG. 8. APPLICATION OF VALVE-IN-HEAD SOOT BLOWERS TO A HORIZONTAL WATER TUBE BOILER, VERTICAL BAFFLE TYPE WITH SUPERHEATER

are eliminated. The header is sometimes equipped with an automatic drain and usually a drain valve located at the low point of the header.

In the top of the operating head is a small air valve which admits air to prevent the formation of a partial vacuum, due to the steam remaining in the pipe, condensing after the control valve has been closed.

Superheaters

SUPERHEATERS effect economy by reducing or even entirely eliminating cylinder condensation, which may run from 10 to 30, and even 40 per cent. In fact, superheated steam loses less heat to the cylinder than saturated steam does. It is more effective.

1. In slow-running than in fast-running engines.
2. In non-condensing than in condensing engines.
3. In non-compound than in compound engines.

The most efficient steam consumption yet recorded is with superheated steam:—only 6.95 lb. per i. hp-hr.

Cleaning Boilers of the Fire-Tube Type

ALTHOUGH fixed soot blowers are coming into more general use for boilers of the fire-tube type, nevertheless hand cleaning equipment is also a necessary adjunct to the well equipped boiler room. Such equipment naturally divides into two general classes: tube

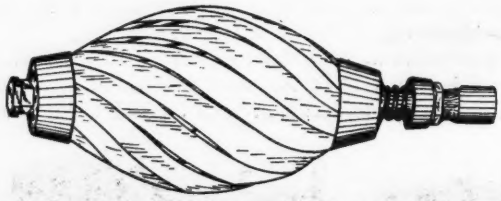


FIG. 1. ELLIPTICAL TYPE OF TUBE SCRAPER

cleaners which are used for removing the scale due to the feed water conditions, and cleaners which are used for removing soot incrustations which have baked on the tube surfaces and which cannot be removed by blowers. Cleaners for removing the feed water scale are

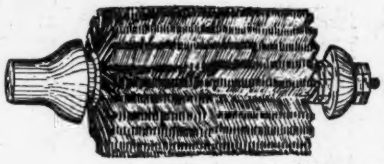


FIG. 2. WIRE BRUSHES ARE FREQUENTLY USED FOR TUBE CLEANING

taken up in another article in this issue and this discussion is therefore limited to the methods of removing soot accumulations.

Flue cleaners have been developed in three general classes. First, the type which has an iron blade that

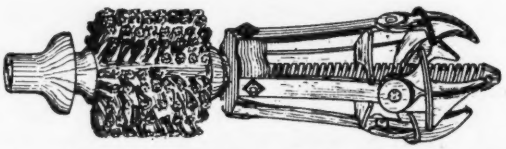


FIG. 3. COMBINATION BRUSH AND SCRAPERS OF THIS TYPE GIVE GOOD RESULTS

operates parallel with the circumference of the tube; second, a steel scraper which operates on an angle or curve against the side of the tube; and third, a wire brush whose bristles act as a quantity of cutting edges. All of these types have also been developed in certain combinations such as a combination brush and scraper. It is also possible to secure a combination type of cleaner which removes the soot accumulations at the same time that it hammers off the boiler scale.

Theoretically a fire-tube becomes dirty due to the natural roughness of its surface catching the solid particles of carbon which are carried through with the smoke. This carbon is in a flaky state which is for the most part easily removed by soot blowers either by the fixed or hand types. Gradually, however, the carbon

bakes on, due to the heat, and requires more than the force of a blast to remove it. In ordinary cases, this layer of soot scale is quite thin and some care must be exercised not to remove a part of the tube metal when the cleaning is being done. For this reason the various combinations of scrapers and cleaners have met with favor, the scraper breaking loose the scale and the brush following, pushing the loosened deposit out of the tube.

Where soot blowers are used, the time between tube scraping may be increased. Some engineers make it a practice to scrape the tubes at the same intervals allowed for cleaning off the boiler scale. This depends, however, on operating conditions and also on how frequently the soot is blown. It will usually be found advisable to scrape or brush the tubes at least once a month even if soot is blown on every shift. Many organizations make a practice of scraping tubes each time the boiler is down. This is especially true where the plant is closed down over Sunday or where reserve capacity gives an opportunity for more frequent cleaning.

Cleaners of this general type are operated by pushing them through tubes. In some cases the cleaner handles used for this purpose are a single rod and there are also jointed rods available which may be extended to the desired length.

In the accompanying illustrations several cleaner heads are shown which are of the type used in this work.

Tests for Good Combustion and Heat Transfer

REGULATION OF AIR SUPPLY; ENSURING MIXTURE OF GASES AND HIGH TEMPERATURE; TESTS OF TEMPERATURES AND ANALYSIS OF FLUE GASES

COMBUSTION is nothing more nor less than a chemical reaction of a simple nature. Fuel, usually in the form of carbon, combines chemically with the oxygen in the air, the reaction liberating a certain amount of heat, depending upon the completeness of the combination. The proportions in which these two elements may combine in this manner may take either of two forms, one resulting in the production of carbon monoxide (CO), and the other in carbon dioxide (CO_2). The former product represents incomplete combustion, the reaction resulting in the liberation of only 4450 B.t.u. per lb. of combustible. The reaction resulting in the production of carbon dioxide, on the other hand, liberates 14,600 B.t.u. per lb. of combustible, and represents complete combustion. The production of CO_2, therefore, is what we are after when we burn coal in the furnaces under our boilers. To bring about this production of CO_2, we must maintain certain conditions of temperature and air supply in our furnaces.

Since air which supplies the oxygen for combustion is composed of only 21 per cent oxygen and 79 per cent nitrogen, it is obvious that a large amount of air will have to be supplied. In raising to furnace temperature that part of the air which is not used (mostly nitrogen), heat from the fuel is diffused and much of it lost. With the knowledge that under fairly good conditions 20 lb. of air should be supplied for every pound of fuel burned, it is readily seen that more or less than enough air causes avoidable losses.

If too much air is supplied, combustion will be complete, but the hot gases will be mixed with excess cold air entering from the outside. This cold air must be heated to the temperature of the furnace by the heat of combustion, and heat which could otherwise have been utilized in heating the water will be wasted.

If too little air is supplied to the furnace, there will not be sufficient oxygen available to complete combustion, CO will be formed and this in escaping up the stack will carry away some 10,000 B.t.u. for every pound of combustible burned. The importance of providing the correct amount of air is obvious.

Complete combustion is not obtained in boiler furnaces receiving only the amount of air required. To insure perfect combustion, it is necessary to supply at least from 30 to 50 per cent more air than the amount of air theoretically required, but even this condition is maintained in only very few plants. In most cases, it runs from 50 to 100 per cent excess and it is often found to be as high as from 100 to 200 or 400 per cent excess.

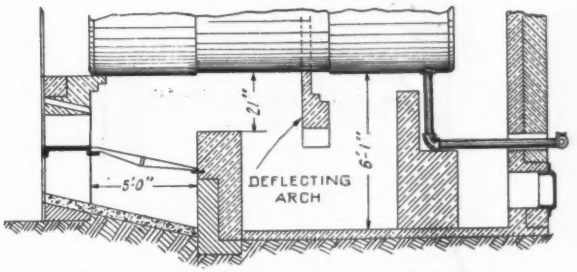


FIG. 1. PLAIN SETTING WITH DEFLECTING ARCH

The majority of boiler plants are operated with too large an excess of air. The conditions conducive to proper combustion as set forth by Arthur D. Pratt may be briefly enumerated as follows:

Admission of an air supply such as will assure sufficient oxygen for complete combustion, but not such as to dilute unduly the products of combustion with excess air.

Air supply must be admitted at the proper time and in such a manner that the oxygen of the air will come into free and intimate contact with the combustible matter in the fuel. In the case of solid fuels, this means not only into contact with the solid particles of the oxidizable substances, but also with the combustible gases as they are distilled from the fuel.

METHODS OF SUSTAINING TEMPERATURE

FURNACE gases must be maintained at a temperature at or above their ignition point until combustion is complete. Theoretically, the most efficient combustion is that resulting in the maximum temperature possible. In practice, there are frequently factors which, from the standpoint of commercial operating efficiency, make it advisable to keep furnace temperatures somewhat below those which could be obtained were this the sole factor involved.

An additional requirement which has to do with the physical rather than the chemical aspect of combustion

is that proper provision must be made for the expansion of the gases during the period of their combustion.

In hand-fired furnaces, about half of the 14 lb. of air required for every pound of soft coal should be introduced above the fuel bed, for the purpose of supplying oxygen for the combustion of the volatile gases which have been distilled from the solid fuel. If this secondary air is not supplied, the volatiles are likely to escape up the stack.

Mixing, agitation, or eddying of the gases will hasten combustion, but the excess of air will still be necessary to complete combustion in a reasonable time. The more thoroughly the air is distributed and mixed with the combustible gases, the less excess air will be required. The gases must furthermore be maintained at a temperature above the ignition point until oxidation is complete.

Use of Deflecting Arches

In order to insure thorough mixing of the gases, it is sometimes necessary to provide suitable baffling, or deflecting arches. In other cases, steam jets are introduced in the furnace, usually just above the fire doors.

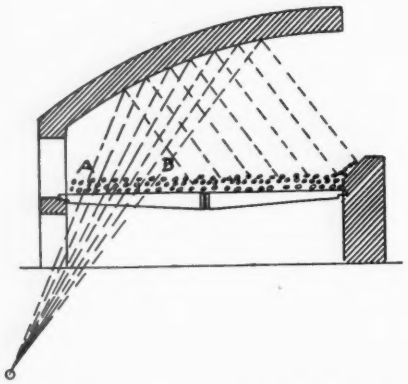


FIG. 2. ARCH FOR CONCENTRATING HEAT RAYS ON NEW FUEL

In Fig. 1 is shown a furnace provided with a deflecting arch at A. This arch turns the gases of combustion downwards at right angles, thereby bettering the mixture and aids in completing combustion. Tests run on this furnace with and without the deflection arch indicated an increase in efficiency of 1.2 per cent through the use of the arch. If no positive means is provided for mixing the gases, they often become stratified in which case combustion cannot be complete.

It was stated above that the temperature of the gases must be maintained above the ignition point until combustion is complete. This is generally best brought about by the use of suitable ignition arches. These, by virtue of their high radiating qualities, cause the volatile gases as they escape from the fuel, to be ignited.

In the deflection of heat from arches we have a means of great effectiveness for igniting the fuel and hastening the process of combustion. When a fresh layer of fuel is placed upon the existing fire, however, it is chilled, and the temperature of the reflecting arch also is reduced. As a consequence, the heat radiation from the arch to the fresh fuel is, in turn, reduced. This condition, naturally, is not to be desired and it has therefore been found advisable to design the brickwork and the reflection arch so that the heat from the old portion of the fuel bed will be reflected upon the fresh fuel. An arch of this type is shown diagrammatically in Fig. 2. This particular type of arch is designed for use with high moisture fuels and produces an intense concentration of heat upon the fresh fuel. As the fresh fuel ignites and burns, it is pushed toward the rear of the furnace until finally it serves to supply the heat necessary for igniting new fuel.

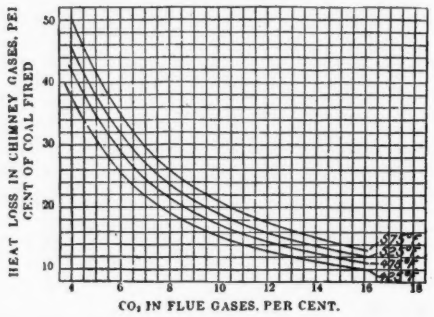


FIG. 3. RELATION BETWEEN PERCENTAGE OF CO_2 IN FLUE GASES AND THE HEAT LOST IN THE DRY CHIMNEY GASES

Temperature Tests of Flue Gases

It is important to measure flue gas temperatures correctly in various parts of the gas passages through the boiler not only as a means of determining the results of combustion, but also to indicate the condition of the boilers. Since the purpose of the heating surface of the boiler is to absorb the heat of combustion, it is obvious that any diminution in the heat absorbing qualities of the heating surface will manifest itself in an increase in flue gas temperature.

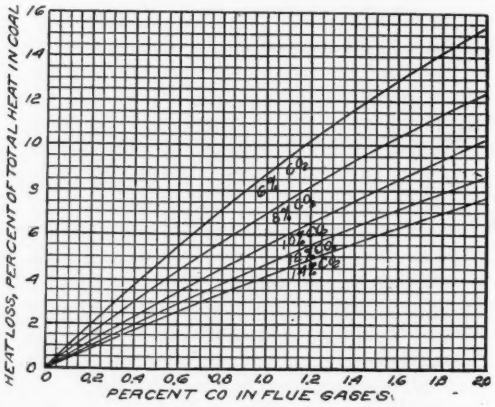


FIG. 4. RELATION BETWEEN THE PERCENTAGE OF CO IN THE FLUE GASES AND THE HEAT LOSSES DUE TO THE ESCAPE OF CO. EACH CURVE GIVES THE LOSS FOR ONE CONSTANT PERCENTAGE OF CO_2 AS INDICATED UNDER EACH CURVE

Many plants are provided with electric indicating or recording pyrometers by means of which the flue gas temperatures may be read at any time. A continuous record of flue gas temperatures is very desirable and in some plants this record is used to determine when the boiler surfaces are to be cleaned.

Where pyrometers are not installed, however, temperature tests are usually made with ordinary mercurial thermometers. These are easy to read and are accurate for all temperatures under 572 deg. F. Special types of mercury thermometers are able to register up to 980 deg. F. Above this temperature, the mercury thermometers are inaccurate and subject the enclosing tube to a dangerously high pressure.

Another method of determining temperatures higher than 1000 deg. is by employing a number of fusible alloys placed in crucibles which are inclosed in a porcelain oven and subjected to the heat of the furnace whose temperature is desired. All alloys whose melting point is below the temperature of the furnace become liquids and by this means it is possible to determine within reasonable limits the temperature maintained in the furnace as metals or alloys can be secured whose melting points are not far apart.

Great care is required in taking temperature measurements of flue gases, as errors of considerable magnitude may result from radiation effects and improper placing of the thermometers. The bulb must be placed directly in the path of the moving gases and must remain in place sufficiently long to assume the full temperature of the gases.

As radiation is the chief cause of error, it is advisable to protect the thermometer or pyrometer bulb by shields or petticoats. By placing the thermometer within a hood of a nonconducting material through which the gases circulate, the radiation error can be reduced to a negligible quantity, although this method does not necessarily give the average temperature of the flue gases, because of their possible stratification.

In practice it is usual to maintain a temperature of about 400 deg. F. in the uptake of the boiler when natural draft is employed upon the furnace. When forced draft is employed, the temperature of the waste gases can be reduced to about 300 deg. F., as the draft is not dependent upon the weight of the gas and that of atmosphere.

Flue Gas Analysis

Flue gas analysis furnishes a check or measure on vitally important factors, which, while they cannot be observed with the naked eye, have considerable bearing on economy and efficient operation. It has been found that there is a definite relation between the percentage of CO_2 in the flue gas and the chimney loss, hence the analysis of the flue gas for CO_2 offers a convenient and accurate gage as to the quantity of air being used for combustion, thus enabling steps to be taken to maintain the best efficiency.

This relationship is expressed graphically in Fig. 3, showing data secured by the United States Bureau of Mines. Taking 475 deg. flue gas temperature for example, it will be noted that with 15 per cent CO_2 (practically perfect condition) the loss of heat in the flue gas amounts to about 12 per cent, an unpreventable loss. With 10 per cent CO_2 in the flue gas, however, the loss amounts to about 17½ per cent (representing a preventable loss of over 5 per cent), while with 5 per cent CO_2 the loss amounts to up to 35 per cent.

In addition to analyzing for CO_2, the flue gases should also be analyzed for CO, as the loss due to burning to CO instead of CO_2 may vary anywhere from nothing to 16 per cent or more. The relation of this loss to the percentage of CO in the flue gases is shown in Fig. 4.

There are upon the market a number of instruments for analyzing the flue gases which are not difficult to operate and which give sufficiently accurate results for practical purposes.

In order to obtain an average sample of gas, a sampling tube should be provided which extends well into the boiler whose gas is to be tested. For this purpose, the Bureau of Mines recommends a water-cooled tube or a quartz tube as preferable to a plain metal tube. An open-ended tube placed in the center of the stream of gases gives with water tube boilers results within 0.5 per cent of the average composition if the setting is tight. For more accurate work a "spider" such as is shown in Fig. 5 may be used.

It is advisable to connect the gas sampler to a water aspirator so that a continuous stream of gases is maintained through the connection. A tee in the line on the upstream side of the aspirator permits a sample to be taken off by the collector or by the analyzing apparatus. Such an aspirator can be constructed of pipe fittings, or a simple aspirator can be purchased. There should be no pockets in the gas line which would fill up from the condensed water vapor always contained in the flue gases.

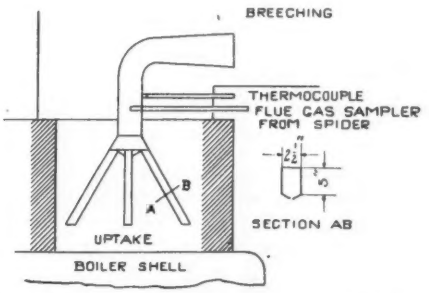


FIG. 5. SPIDER USED FOR OBTAINING PROPER SAMPLE OF FLUE GASES FOR TEST

Samples should be taken continuously if possible. One gas sample per hour is very little better than no sample at all. It is not enough to indicate an average. The sample should be taken every 5 min., although a continuous sample is better. Speed is essential in taking a gas sample, as conditions may change from instant to instant. The conditions at the time of taking the sample should be recorded in order to be able to determine the meaning of the analysis.

One of the principal causes of smoke is lack of sufficient air at the proper temperature at the point where the volatile gases from the coal should be burned. This being the case, it is evident that by observing the smoke emitted by the chimney, one can form an approximate idea as to the effectiveness of combustion. An excess of dense, black smoke is in all cases an indication of inefficiency. At the same time, it must be remembered that an entire absence of smoke does not necessarily indicate perfect combustion, for it may be that a great excess of air is being supplied, resulting in an even higher loss than would be caused by combustion producing smoke.

Temperature Indicating Instruments

KNOWLEDGE OF FLUE GAS TEMPERATURES PROVIDES A CHECK ON THE CONDITION OF THE BOILER AND FURNACE

MOST OF the heat lost in the operation of any furnace is that carried away in the flue gases. Every pound of air that passes through the setting must be heated to the existing flue gas temperature and must of necessity abstract a certain amount of heat from the fuel that might otherwise be used to advantage in generating steam. In the interests of efficiency and economy it is necessary, first, to keep the excess air to an absolute minimum and, second, to keep the flue gas temperature at the lowest possible point. Were it possible under actual operating conditions, as it is in the laboratory to reduce the flue gas temperature to that of the surrounding atmosphere, the amount of excess air used would have absolutely no effect on the efficiency; there would be no loss of heat in the flue gases even with 1000 per cent excess air.

This, however, is not economically feasible in actual practice and it is necessary to control the air excess and economy will result by keeping the flue temperature as low as possible. Consider a boiler generating steam at say 140 lb. abs., at a temperature of 353 deg. F., where the flue gas temperature is 600 deg. F. The avoidable loss of heat chargeable to the inefficiency of the boiler is that represented by a temperature rise of $600 - 353 = 247$ deg. F. Assume now that for every pound of fuel burned there passes through the setting 20 lb. of flue gas. This gas, having an average specific heat of 0.25, will absorb $20 \times 0.25 \times 247 = 1235$ B.t.u. per lb. of fuel fired. If the coal burned has a heating value of say 12,000 B.t.u. per lb., this loss represents $1235 \div 12{,}000 = 10.3$ per cent of the potential heat in the coal. If the gas temperature can be reduced to 450 deg. as it can with clean heating surfaces and low excess air, the saving is 150 deg., representing 750 B.t.u. or 6.25 per cent of the heat in the fuel.

To be sure then that the boiler and furnace is working at best efficiency, it is highly desirable that means be provided for keeping a constant check on the flue gas temperature. An analysis of the variations in this temperature will tell the fireman when his tubes need cleaning, when it is time to blow down the soot accumulation, when a baffle is down, and will also serve as a check on the draft readings.

To secure this information requires the use of some temperature inndicator such as a mercury, gas, or vapor thermometer or a thermo-couple or resistance pyrometer. For determining furnace temperatures, either of the two mentioned pyrometers or an optical or radiation pyrometer may be used.

FIG. 1. BULB OF A GAS THERMOMETER

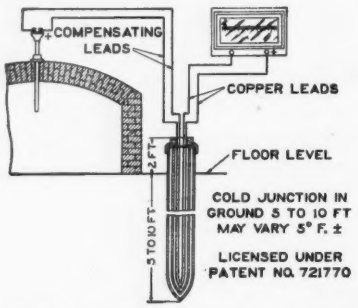

COMPENSATING LEADS
COPPER LEADS
2 FT.
FLOOR LEVEL
COLD JUNCTION IN GROUND 5 TO 10 FT MAY VARY 5° F. ±
5 TO 10 FT.
LICENSED UNDER PATENT NO. 721770

FIG. 2. DIAGRAM OF CONNECTION FOR A THERMO-COUPLE PYROMETER

Mercurial thermometers are perhaps the most familiar to all of us. Their range is limited, however, as the boiling point of mercury is 676 deg. F. at atmospheric pressure and at temperatures approaching the boiling point they are unreliable. To obviate this difficulty, the space above the mercury column is filled with some inert gas such as nitrogen under considerable pressure. This, of course, raises the boiling point materially and renders this type of thermometer useful for temperatures up to 1000 deg. F. Most mercury thermometers are constructed with the indicating scale immediately adjacent to the bulb. In this form they are not particularly suitable for measuring flue gas temperatures, as it would be necessary to climb up to the breeching to obtain a reading.

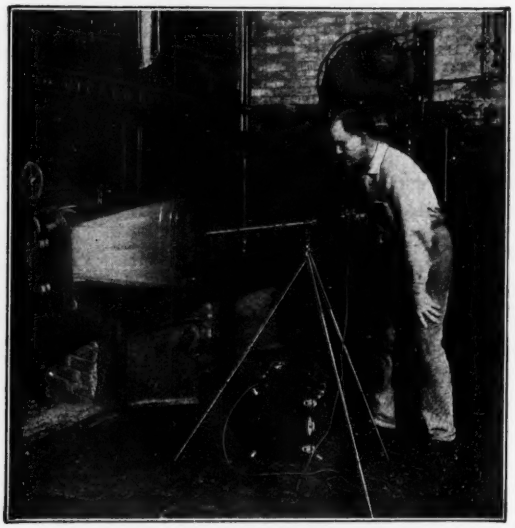


FIG. 3. RADIATION PYROMETER IN POSITION FOR INDICATING FURNACE TEMPERATURE

Gas thermometers depend upon the variation in pressure in a confined quantity of inert gas due to variations in temperature for their operation. The apparatus consists of a bulb containing the gas, such as shown in Fig. 1, which is subjected directly to the temperature

to be measured. This bulb is connected by a capillary tube to the indicating or recording mechanism where the pressure acts on a form of Bourdon gage or spiral flat tube to cause a movement there. This movement is communicated through amplifying gearing to a pointer moving over a scale graduated for temperature.

Vapor thermometers are similar to the gas thermometer with the one exception that instead of an inert gas a vapor is used. Variations in temperature affect the vapor tension and variations in the intensity of this tension are indicated as degrees of temperature. The chief advantage of these two types of thermometers is that the indicator or recorder may be located at a considerable distance from the bulb without introducing appreciable errors. Temperatures as high as 1500 deg. F. may be used with these thermometers.

Temperature may be measured by the difference in expansion of two metals such as copper and iron. As usually constructed, the instrument consists of a

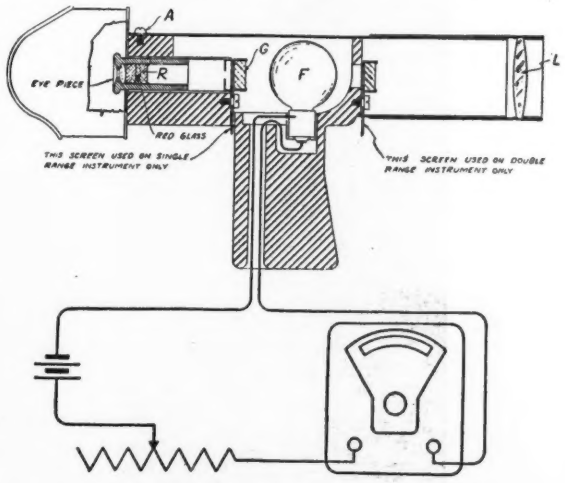


FIG. 4. SECTION OF AN OPTICAL PYROMETER

copper tube or rod within an iron tube, rigidly fastened together at the outer end. As the coefficient of expansion is different for these two metals, any variation in temperature will cause a difference in the distance between the free ends of the two tubes. This relative movement is communicated through a system of gearing to a pointer working on a scale calibrated to read temperature. Such a thermometer is likely to be sluggish in its action owing to the relatively large amount of metal that must be heated; it must necessarily be of the direct-connected type.

Resistance pyrometers or thermometers consist of a coil or wire through which a small electric current is made to flow. The resistance to this flow varies with the temperature of the resistance element, hence by balancing this resistance with a known resistance on a wheatstone bridge we have a measure of the temperature. A variable resistance is provided and the scale calibrated to read temperature.

In the thermo-couple pyrometer, the juncture of two dissimilar metals is subjected to the temperature to be measured. There is an electromotive force established between the two metals which is proportional to the temperature. This electromotive force, which is exceedingly minute, may be indicated on a milli-voltmeter whose scale is calibrated in degrees of temperature. For accurate work there should be a cold junction which may be maintained constant at any predetermined temperature; thus variations in room temperature have no effect on the readings. Various combinations of metals may be used for the thermo-couple. Where the temperature is not excessive base metal alloys such as nickel-chromium and constantan may be used. But where greater sensitiveness is required or where the temperatures are high, a Platinum-Rhodium combination is used. Figure 2 shows the diagrammatical connections for recording temperature by means of a thermo-couple pyrometer.

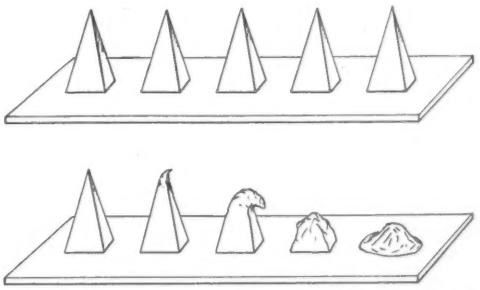


FIG. 5. CLAY CONES BEFORE AND AFTER BEING SUBJECTED TO THE FURNACE TEMPERATURE

Where the temperature to be measurd is exceedingly high direct contact thermo-couples are too likely to be damaged and in these cases a radiation pyrometer is more suitable. In this instrument, shown in Fig. 3, set up for taking a reading, rays of heat from the furnace enter the pyrometer tube and are reflected from a concave mirror onto a sensitive thermo-couple at its focus. Temperature is indicated on a milli-voltmeter just as with the usual type thermo-couple pyrometer.

Optical pyrometers are also used where it is undesirable to make a direct contact with the temperature to be measured. In this instrument, a section of which is shown in Fig. 4, the color of the flame or body whose temperature is to be measured is compared with that of the filament of an incandescent light. The filament temperature and therefore intensity of light may be varied by cutting in resistance in its circuit. Current through the filament is measured by a millammeter calibrated to read degrees temperature of the filament and consequently also of the source of heat being measured.

Another method sometimes used for measuring the temperature of the furnace or the fuel bed is borrowed from the ceramic industry. It consists in placing in the furnace a series of clay cones of varying composition having different known fusing temperatures. These cones on being subjected to the furnace temperatures will begin to soften and collapse. Those having a fusing temperature below that of the furnace will fall first and the higher temperature cones will follow in turn. The approximate temperature of the furnace is indicated by the cone whose tip just begins to collapse. In Fig. 5 is shown a series of such cones before and after having been subjected to the furnace temperature. In this case the known fusing point of the second cone from the left corresponds to the existing furnace temperature.

Flue Gas Analyzers and CO_2 Recorders

PRINCIPLES AND METHODS OF USE OF HAND ANALYZERS, METHODS OF GETTING CORRECT GAS SAMPLES, TYPES OF RECORDERS

BECAUSE of the importance of making flue gas analysis there have been developed a large number of gas analyzers, both indicating and recording. While each make possesses certain features of construction which serve to distinguish it from the others, the principles of action in most cases are similar. Most of the

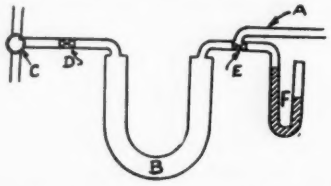


FIG. 1. CO_2 INDICATOR EMPLOYING SOLID CAUSTIC POTASH AS ARSORBENT MEDIUM

recording instruments operate upon the principle that CO_2 is absorbed by a solution of caustic potash or other absorbing material.

One of the most common and also, perhaps, the most widely known, is the hand Orsat apparatus with which every engineer is familiar. This instrument needs

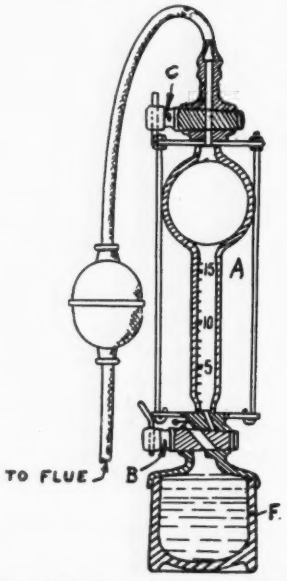


FIG 2. DIAGRAM OF INDICATOR SHOWN IN FIG. 3

no description, either as regards construction or operation; but it may be well to call attention to certain improvements which have been brought about in this apparatus for bringing the gas to be absorbed more actively in contact with the absorbing solution. It had been noticed that the bubbles of gas, in passing through the absorbing solution, did not allow the molecules of gas at or near the center of the bubble, to come in contact with the solution. To bring about a more intimate contact between the gas and the solution, various materials were inserted in the absorber containers. In one make the containers are packed full of short lengths of glass tubing. These tubes are immersed in the absorbing solution and serve to break up to some extent the formation of large bubbles. In one gas analyzer the gas is passed through receptacles filled with steel wool. The steel wool is even more effective than the glass rods in breaking up bubbles and a high degree of absorption is obtained.

CO_2 INDICATORS

THE ORSAT apparatus is usually employed to determine not only the percentage of CO_2 but of O_2 and CO

FIG. 3. INDICATOR EMPLOYING PRINCIPLE OF REDUCED VOLUME BY ABSORPTION

as well. Where only CO_2 determinations are required, there are available a number of CO_2 indicators.

In one indicator the CO_2 is absorbed by solid caustic potash. The reduction in pressure of the sample due to CO_2 absorption is read directly in percentage of CO_2 on a mercury gage. Referring to Fig. 1, flue gases from A are passed at high speed through the metal U tube, B containing the caustic, under the action of the aspirator at C. Practically no CO_2 is absorbed in this rapid passage, but on shutting off communication by means of the cocks D and E, absorption begins. The maximum reduction in pressure is read on the mercury gage at F.

In using the instrument shown in Figs. 2 and 3, gas is pumped into the measuring tube A by the bulb R. The upper valve C is now closed and the lower valve B opened to connect with the caustic potash solution below. With the valves in this position, the device is rocked back and forth until the CO_2 in the sample has been absorbed. The caustic is now shut off and the instru-

ment inverted with the valve C under water. When the water reaches the same level inside and out, it indicates that the residual gas is at atmospheric pressure. Upon reversing, the CO_2 originally present is indicated on the scale by the height of the column of liquid. This instrument weighs only 1½ lb. and will make 200 determinations with one filling.

Another make of indicator is of the same general type as the one just described, except that in this case the reduction in pressure of the sample due to CO_2 absorption is registered in percentage of CO_2 on a pressure gage.

In what is known as a CO_2 thermoscope the heat generated by the union of the CO_2 in flue gas and granular caustic alkali, gives an indication of the amount of CO_2 in the sample. A definite quantity of the flue gas is drawn through the cartridge containing the absorbing crystals; this cartridge is surrounded by a specially

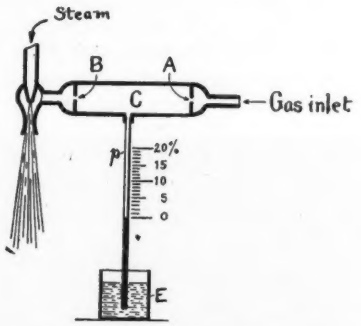


FIG. 4. PRINCIPLE OF RECORDING METER BASED ON CHANGE IN PRESSURE

constructed thermometer which indicates the temperature rise due to the reaction which is proportional to the percentage of CO_2 in the gas being tested. The scale of this thermometer is, therefore, graduated to read directly in per cent CO_2.

Other instruments depend upon the variation in electrical resistance of a solution of caustic potash upon exposure to the flue gas sample.

Recorders

While the Orsat apparatus and the various types of CO_2 indicators described are reliable and accurate, they are useful only in making occasional tests. Where a continuous record of CO_2 conditions is desired, a recording instrument must be used. The recorders, as stated previously, operate upon the same basic principles as the indicators and the Orsat, but have in addition, various arrangements for periodically collecting and measuring a sample of gas, and recording the determination automatically. Most of the recorders are operated by the flow of water, which not only draws the gas into the instrument, but also furnishes the motive power for actuating the instrument. Some instruments, however, are electrically driven. In at least two instruments the gas is drawn in by a steam operated aspirator. One of these recorders furnishes a continuous (not intermittent) record of the CO_2 content in the flue gas.

In this machine, the principle involved depends upon the change in pressure caused by a change in volume in a stream of gas flowing through two apertures. The manner in which the meter utilizes this physical law will be understood by referring to Fig. 4. A continuous flow of gas is caused to pass first through the aperture, A, and then B by means of an aspirator or syphon, as shown. Reducing the gas volume between the two apertures by absorbing the CO_2 content causes a change of pressure in chamber C which is transmitted to a recording gage or manometer tubes calibrated in per cent CO_2. This machine uses the dry method of absorption, the absorbent being in the form of a dry

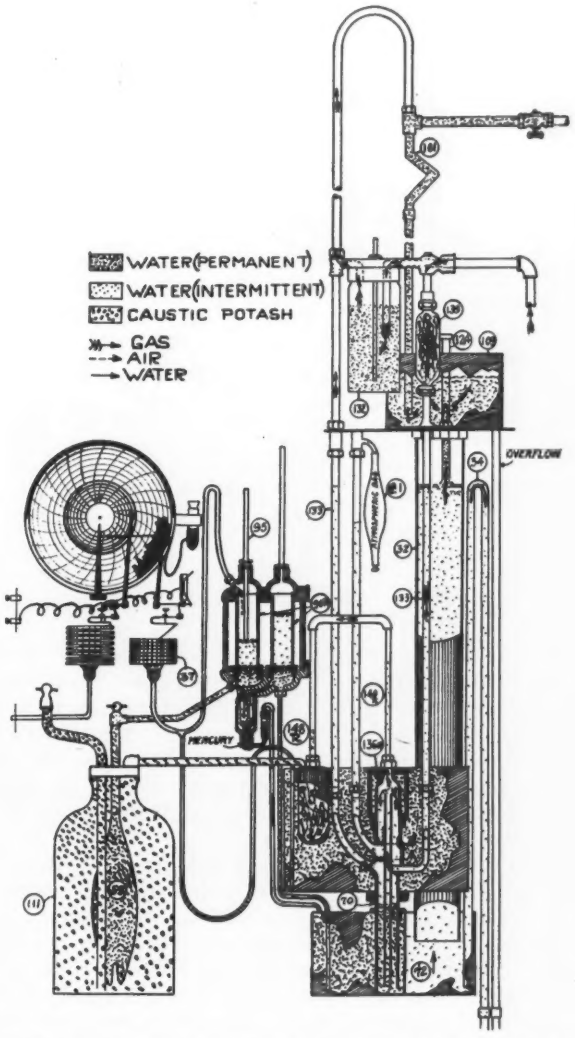


FIG. 5. DIAGRAM OF RECORDER EMPLOYING ORSAT PRINCIPLE

cartridge readily removed and replaced like a dry battery.

Figure 5 is a diagram of a recording machine which is typical of those based upon the Orsat apparatus. A continuous stream of gas is drawn rapidly from the last pass of the furnace and at regular intervals the machine takes a measured sample of this gas, causes the CO_2 to be absorbed by means of caustic potash solution and the pen to move on the chart representing the per cent by volume of CO_2 contained in it. Such variables as temperature and pressure of the gas sample, evaporation of water and changes in the specific gravity of the

caustic potash solution are automatically controlled by this machine.

In another design of CO_2 recorder, the CO_2 is absorbed by a caustic solution, the amount of residual gas being indicated by an oil actuated float. The instrument is operated by the syphoning action of water, of which about two barrels a day are required.

One of the more recently developed types employing liquid caustic potash for CO_2 absorption measures the residual gas in a gasometer and the decrease in volume is

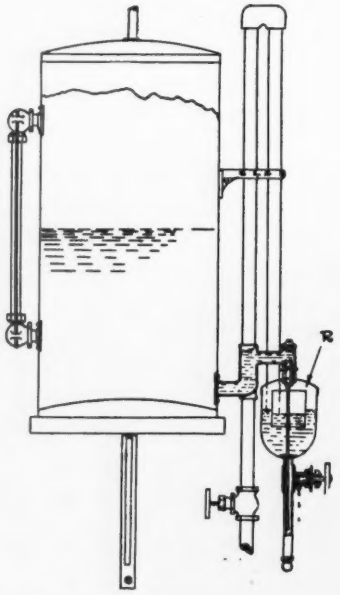


FIG. 6. AUTOMATIC GAS COLLECTOR

recorded on a chart. The duplex recorder of this type records both CO_2 and CO on the same chart. Alternate samples are exposed before analysis to the action of heat in an electric oven. Any CO present unites with oxygen and forms an equivalent volume of CO_2. The analysis from the samples which have passed through the oven therefore indicates higher values if there is any CO present.

In some types of recorders a measure of the density of the flue gas is used to determine the CO_2 content. In one design the percentage of CO_2 is determined by actually weighing the flue gases before and after the CO_2 has been absorbed. In another recorder the difference in density between the gases and pure air is measured by a differential pressure gage. The CO_2 is read from the position of a column of colored liquid of which a continuous photographic record is made.

Among those belonging to the automatic Orsat class is a machine which uses caustic potash as the absorbing material and measures the gas by means of two inverted bells, which are the only moving parts with the exception of the clock itself.

Slaked lime packed in a box with excelsior is the absorbing material used in one machine. The gas is measured by means of small gas meters before and after absorption, the recording pen being actuated by means of a differential drive operated by the two meters.

One other recorder may be mentioned as being of interest because of the fact that no absorbing medium is required. It consists essentially of two small fans driven at constant speed by an electric motor combined with a balance which measures the difference in the pressure differentials produced by the two fans.

Getting a Correct Sample

In making a gas analysis, whether by means of a recorder or by means of a hand apparatus, one of the difficult things is to obtain a proper sample of gas. With the recorder, it is best to have a constant, steady stream of gas flowing at all times by means of some sort of aspirating arrangement. The recorder is so arranged as to draw the sample from this steady stream of gas whenever it goes through a cycle of its performance.

With a hand apparatus, it is generally desirable to obtain an average sample over a certain period of time. Now, this may seem simple, yet it is rather difficult unless proper apparatus is at hand.

For instance, it might be assumed that an average sample could be obtained by filling a tank with water, connecting this tank with the source of gas supply, waste the water from this tank and allow the gas to come in as the water flows out. A moment's thought, however, will suffice to prove that by this means an

FIG. 7. TYPICAL CO_2 RECORDER INSTALLATION

average sample would not be obtained. The flow of water from the tank will be in proportion to the "head." The "head," however, will vary as the water level falls. It is apparent, therefore, that such a contrivance will draw gas many times faster at the beginning than at the end of the sampling operation.

To overcome the error introduced by the variation in head, it is advisable to provide the water outlet of the tank with some sort of regulator. A device of this type is shown in Fig. 6. The regulator "R" insures a constant rate of discharge from the tank.

Another thing that should be watched in taking a gas sample is the position of the sampling tube in the flues. Make sure that the intake end of the sampling tube is at the center of the gas flow and at the place where the gases leave the heating surface of the boiler.

In checking a CO_2 recorder for accuracy, connect the intake tube of the hand analyzer directly above the recorder and slowly pump a sample of gas at the same time that the recorder is drawing its sample. This analysis should agree with the next stroke of the re-

corder pen. Make several such analyses. If a considerable variation is noted between the recorder and the hand apparatus it may be assumed that the recorder is faulty.

Results and Deductions

Determination of the percentage of CO_2 in the flue gases is of the greatest importance. If combustion is complete, there will be no CO in the flue gases; when incomplete, CO will be formed and this condition is usually accompanied by the production of smoke. A visible indication of incomplete combustion is always present at the top of the stack, but analysis for CO_2 in the gases is the only method available for showing an excess of air. The proper percentage of CO_2 to be carried in any plant must be determined for that plant individually; it should, of course, be as high as possible without the presence of CO. At some plants 14 per cent may be obtained with only occasional traces of CO, while others may show considerable incomplete combustion as indicated by the presence of CO, when the CO_2 is as low as 8 per cent.

Methods for Smoke Detection

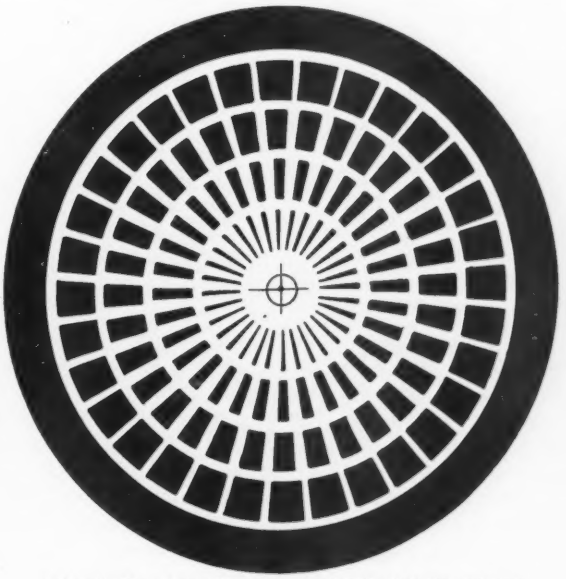
Most Efficient Furnace Operation Is at the Point Point Where a Faint Haze Appears at the Stack

IN THESE days when almost every city has in force a smoke abatement law to compel the elimination of smoke, it behooves the power plant operator to keep his stack clear. This does not mean, however, that he is merely to open his ash pit doors and admit excess air without having some idea as to the quantity of air involved. It is a comparatively simple matter to burn almost any kind of fuel in any kind of furnace if plenty of air is used. Excess air is productive of enormous waste by throwing away heat up the chimney. consequently it is necessary to keep the amount of excess down to minimum—down to the point where carbon monoxide and smoke just begin to form. There is a very scant latitude between highest furnace efficiency and a smoking condition of the stack, and hence it is desirable that some means be provided to keep track of the condition of the flue gases as regards smoke density.

It is of course possible for the fireman to go out and look at the stack at frequent intervals, but it is seldom that he can be relied upon to do that. If he is to watch the smoke it must be easy for him to do so. Where the stack is not visible to the fireman from his position in front of the furnace mirrors have been used, so located outside of a window that the top of the stack could be seen from the boiler room. While this answers the purpose fairly well under certain conditions, it is of little, if any, use on dark days. For indicating smoke a device has been developed which is provided with an artificial source of illumination and is therefore useful even after dark. The construction of this apparatus is quite simple. An electric lamp is fitted with a suitable reflector and a strong single convex lens, placed at the end of a short tube which is attached to one side of the breeching at, or near the last pass of the boiler setting. A short tube fitted with a clear glass is placed on the opposite side of the setting or breeching in direct alinement with the lamp reflector and single convex lens, thereby directing a shaft of light across the breeching at right angles to the flow of chimney gases. By means of elbows fitted with mirror reflectors and hung so that the mirror is at 45 deg. to the shaft of light, a reasonable number of right angle turns can be made. The light is finally projected onto a ground glass screen fitted into a hood arrangement, which screen diffuses the light into a large full moon effect.

As the smoke content of the chimney gases varies, the moon effect is more or less eclipsed from clear to a total eclipse. The sight-box or gage can be placed at any convenient point in the boiler room suitable for the furnace operator's observation.

When the breeching is clear, the beam of light shines across the path of the flue gases and registers as a light area on the screen. As smoke begins to appear, some of the light is cut off and the screen appears darker. The different degrees of light intensity thus produced



ADAPTATION OF THE RINGELMANN SMOKE CHART

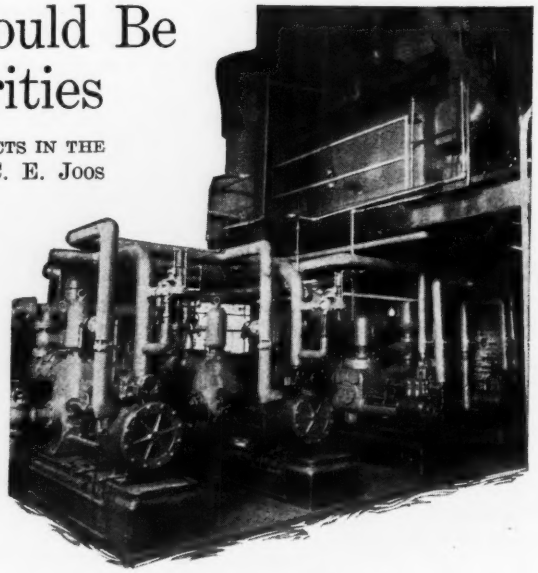
may be compared with a standard smoke chart such as the Ringelmann, and a record of the observations may be kept. These smoke indications will tell the fireman when his furnace is functioning properly. If the indicator is black or too dark, he knows that his fire is not getting enough air; if it is perfectly clear, it may be getting too much and he should cut down on the supply until a faint haze appears.

For the purpose of comparing smoke observations, some kind of standard is necessary. The generally accepted criterion is the Ringelmann chart which consists of six cards, the first, No. 0, being all white and the sixth, No. 5, all black. The intermediate ones are ruled in squares with lines of such width as give the desired shade when viewed at a distance. No. 1 is 20 per cent black, No. 2, 40 per cent, and so on.

In the accompanying figure is shown an adaptation of the Ringelmann chart. The six charts showing varying percentages of black are arranged concentrically on a circular card which may be mounted on a pivot and rotated at such a speed as will blend the black and white areas and produce even gray colors of varying values. This chart may be observed at close range and easily compared with the stack that is being watched.

Boiler Feed Water Should Be Freed From Impurities

THOSE MOST COMMONLY FOUND, THEIR EFFECTS IN THE BOILER AND WHAT TO DO ABOUT IT. BY C. E. JOOS



OFTEN WE ARE amazed at the action of water, apparently so simple in its chemical composition, when used in a boiler. Water alone, however, is not the trouble maker, but the impurities that it gathers due to its solvent and mechanical action. This acquirement of matter from mineral beds through which it passes is greatly accelerated by the absorption of corrosive gases, chiefly carbon dioxide, from the atmosphere.

Any corrective treatment has for its objects to prevent: 1. Scale. 2. Corrosion. 3. Priming and Foaming. 4. Caustic Embrittlement.

SCALE

THIS IS, perhaps, the most familiar and troublesome to engineers of the above conditions. Its chemical composition has a decided bearing on its heat conductivity, but all scale is to be avoided. If it is true, as some authorities state, that 1/16 in. of scale causes a fuel loss of 13 per cent, ¼ in. a loss of 38 per cent and ½ in. a loss of 60 per cent, surely proper conditioning of the feed water for a boiler is worthy of the best attention that any engineer can give it.

Calcium sulphate is by far the most objectionable variety. If allowed to concentrate so as to crystallize out, this salt will act in much the same manner as a hydraulic cement, binding the other materials into a hard tenacious mass. The carbonate variety, while objectionable, is somewhat porous and easily removed. The two varieties can be easily distinguished by an examination of their cross sections; sulphates show a hard crystalline structure, while the carbonates have the appearance of baked mud. Chemically, they are distinguished by their action in dilute hydrochloric acid, the carbonates being easily dissolved while the sulphates dissolve slowly or not at all.

CORROSION

USUALLY this is due to acid in the water, either free in solution or formed by the action of heat and pressure on otherwise neutral salts. In this action, magnesium chloride is, perhaps, the worst offender, although the writer has seen corrosion due to common salt in moist condition and to carbon dioxide in the gaseous state. These last usually confine their depredations to the steam lines and economizer tubes, and it is the opinion of the author that in economizers, carbon dioxide is more destructive than dissolved oxygen.

As indicated above, water may contain salts that are in themselves harmless, but when subjected to boiler pressures and temperatures are converted into injurious forms. An instance is when magnesium sulphate and calcium or sodium chloride are present together. The magnesium sulphate swaps acid atoms with the chloride, yielding magnesium chloride and calcium or sodium sulphate. The former breaks down into magnesium hydrate and hydrochloric acid, which acid attacks the boiler plates while the hydrate tends to cause foaming. The sulphate of calcium deposits in the form of hard scale. Once the acid starts to work, the eating away is rapid, for the bubbles of acid gas cling to the rough surfaces of the pits or grooves, digging in deeper and deeper until the condition of the plate becomes dangerous.

Corrosion due to electrolysis can usually be traced to stray currents where the feed or blow off line is used as the ground connection for an electrical circuit; or currents are set up within the boiler between different metals such as brass, copper and iron. These cases are rare and may be cured by disconnecting the electric circuit, in the former case, and in the latter by placing a plate of zinc in the corrosive area to divert the current from the boiler plate, or, more simply, by replacing the brass or copper fittings with a metal having the same structure as the boiler plate. When zinc is used, 1 sq. in. of zinc surface will care for each 50 lb. of water in the boiler, and the zinc plates should be renewed when their surfaces have been disintegrated to ¼ in. in depth.

PRIMING AND FOAMING

BOTH EFFECTS may be termed surface conditions. Foaming may be best described by comparing it to the lather formed by soap. A mass of bubbles exists over the entire surface of the water, usually due to a highly alkaline water or to organic or vegetable oils combining with the reagents used to treat the water, forming a soapy compound.

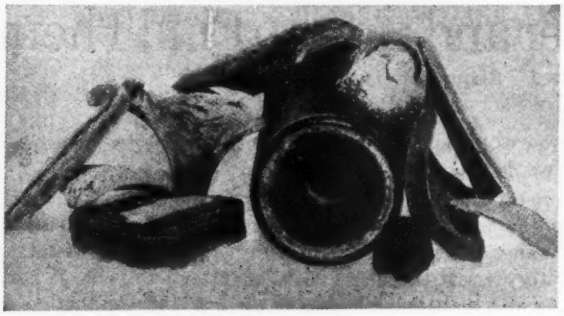
Priming, on the other hand, is a matter of surface tension, due to sodium salts in solution, the sulphate being the chief aggravator. In simple terms, these salts form an armor over the surface, resisting the effort of the steam bubbles to break through, until the pressure beneath the surface is built up to the degree that a miniature explosion takes place, resulting in a rush of steam which carries up with it slugs of water. This condition can be easily observed in the laboratory by boiling rapidly water containing a large amount of soluble material. Evaporation will take place intermittently, in a bumping, noisy fashion, and at times so violently that the water will be partially expelled from

the container, similar to the slugs that are common in priming boilers.

Aside from the danger to reciprocating units and turbines, priming is bad in increasing the friction in piping, due to the deposits left by the wet steam, coating and cutting of turbine blades, need for increased lubrication, and wasting heat because the water thrown out has taken fuel to heat it, but is of no use in furnishing power. Where priming occurs, it is not uncommon to have deposits collect in superheater and steam lines to such an extent that valves cannot be closed.

Besides concentration of soluble salts, priming may be caused by rapid change in load, high water, forcing, and to some extent by the type of boiler. Some of these are difficult of control, but keeping the water level such as to give plenty of disengaging surface for the steam and regulating the concentration of the water by regular testing of the water and frequent blowing down will help to a marked degree. Vertical tube, inclined tube and horizontal tube boilers are susceptible to priming in the order given.

Nearly always, when priming occurs with low concentrations, the cause can be traced to oil contamination of the feed water. As little as 1 grain per gallon of oil may interfere seriously with the free generation of steam. Where caustic soda is contained in the boiler, compounded oils cause the greatest trouble, as they form



SAMPLES OF WHAT HARD WATER CONTAINS

soap and greatly aggravate conditions. It is best to change to a pure mineral oil, and take steps to eliminate it from the feed and condensate.

Caustic Embrittlement

Authorities differ as to the cause of embrittlement, but the commonly accepted theory is that caustic soda works its way into the seams of the boiler drum or shell and by its action in this condition, nascent hydrogen is released and absorbed by the iron or steel. This changes the structure so that it becomes similar to cast iron and, therefore, brittle. Most trouble of this nature is found in those western states where the water is naturally alkaline. It should be remembered that it is not necessary that caustic soda be present in the feed water; if normal carbonate or bicarbonate be present, these may change under the action of heat and pressure into the caustic form, the conversion amounting to as high as 80 per cent, depending on the pressure and the amount of organic matter present; the former aids the change and the latter retards it. Obviously, the remedy is to remove the salts which cause causticity, which may be done by judicious use of lime.

Softening Systems

All such systems have for their object removal of salts of calcium and magnesium from the natural waters to such an extent that the remainder will be non-scale-forming. The two great divisions of the systems are the lime-soda and the zeolite methods. Of the former, the most common are (1) the continuous, and (2) the intermittent batch.

In the continuous system, water is constantly flowing and is treated in transit, the chemical reagents being automatically introduced in proportion to the amount of water used. After treating and settling, the water

IT PAYS TO PREVENT THIS KIND OF THING

is sent through filters, thence to the feed system. It is the writer's experience that with such a system, great care must be taken to insure that the reagents are thoroughly mixed with the water because of the comparatively short time that is allowed for the reactions and precipitation. Otherwise the reactions are not completed until the water enters the boiler and some of the scale-forming material passes to the plates. The hot process is more rapid and effective than the cold, because the reactions are hastened by heat and need for excess chemicals is lessened. The temperature to be preferred is near the boiling point, 212 deg. F.

With a properly designed intermittent-batch system, and plenty of time allowed for precipitation, the use of filters becomes unnecessary. A definite amount of water is treated with the requisite reagents, well agitated either by air or mechanical means and the sediment allowed to settle out, the length of time required depending on the temperature of the water and the kind of solids to be removed. It is necessary to use several tanks for the treating so that a supply of water may be always on hand, but it is easy to get exactly the right amount of reagent into each batch of water and to mix them thoroughly.

Zeolite

This method of softening depends for its action upon minerals from which the system gets its name. These may be natural or artificial and in chemical terms are sodium-aluminum-silicates. They have the power of exchanging their sodium content with the water for calcium and magnesium when the water is passed through a bed of the material. After the mineral bed is saturated with the scale-forming salts, the action is reversed by introducing a solution of common solt (sodium chloride), which is allowed to remain in contact with the zeolite bed until the calcium and magnesium are reexchanged for sodium from the solution. The salt solution is then drawn off and the zeolite bed is ready for repeat the process.

Other Methods

Where plants are too small to justify the installation of elaborate softening systems, two other methods

are in use. The first is the use of boiler compounds; the second standard chemicals used in the boiler under careful control.

Boiler compounds should be made with careful regard for the water to be treated and, if surface waters are used, regular tests of the treated water, drawn from the boiler, should be made to insure that the treatment is effective.

Use of standard reagents under chemical control merits more attention than it usually receives and surprising results are attained when followed systematically and conscientiously. Analysis is made of the water and recommendations of the proper chemicals, using only those standard to water softening practice such as soda ash, caustic soda, lime, silicate of soda and trisodium phosphate. The specified material is fed through an open heater, hot well, or directly into the boiler, the amount varying with the water used. Water drawn from the boiler is tested each day for excess of chemicals, the proper excess being determined by tests for residual scale-forming salts. In brief, this is a method for softening the water scientifically, in the boiler instead of outside.

Chemical Control

Installing a softening system of any kind is not an insurance against scale. Without the proper guidance, the most elaborate system will turn out to be a dismal failure. It should also be stated that no one system is a remedy for every condition. Cold process lime and soda systems may leave deposits in feed lines if the mixture is not thorough or time is not allowed for the reactions, which will be completed in places where the water is heated. The quantity of deposit will depend on heat and friction which tend to hasten the reaction and the separating out of sediment, while some organic matters act as retarders. In case of an acid water, the mineral in a zeolite bed would soon be destroyed, so that additional treatment is needed to neutralize the acid before sending to the zeolite plant.

To get results with any system, the water within the boiler should be tested regularly for excess of alkali and for salt concentrations, and these tests should be watched in the proportioning of the softening treatment. By study of these excesses within the units of the system, important information can be obtained. Leaky valves, broken baffles and priming can be detected by tests of the salt concentrations and every engineer will be well repaid for careful study and investigation of his individual feed problems.

Remember that if a water contains but 10 grains of impurities per gallon and is used to feed a 100-hp. boiler operating 24 hr. a day, there will be deposited or blown out 86 lb. of mineral matter a week.

Causes of Hardness in Water and How to Find Them

Tests for Impurities, Treatment Required, Apparatus Used and Results Which May Be Secured by Proper Care

WHAT IS hard water? Every engineer who has had trouble with diseases of his boilers caused by the effects of hard water will agree that it is at least as serious in its effects as hard liquor; but the first thing we need to know is, what constitutes hard water and why should such water make trouble in the steam generating system?

Water which looks dirty may be quite soft, for the dirt is merely suspended matter which can be easily strained or filtered out. Hardness is caused by mineral matter in solution. We all know that common salt will dissolve in water, and there are other combinations of minerals mostly of sodium, calcium and magnesium which will dissolve in water; but when the water is evaporated, these salts remain behind to form a mass on the tubes and plates.

Two kinds of salts with which we often have to deal are the carbonates and sulphates. The former constitute temporary hardness and are to a large extent thrown down from the water when it is heated to 200 deg., and if carried into the boiler make a soft scale not difficult to remove. The sulphates are not easy to get rid of. Some portion of them is thrown down as a precipitate at temperatures above 300 deg., but this action is slow. These sulphates together with the small amount sometimes found of chlorides and nitrates constitute the permanent hardness of water.

One other class of impurities, called corrosives, are practically all acids which may come into the water from sewage or may be liberated from some of the mineral salts, due to the action of heat. If these acids get into the boiler, they will eat the metal in patches, in pits or grooves, which usually occurs near the joints or around rivet holes.

Oil and grease must also be taken care of, if found in the water. For not only do they form a non-conducting coating on the heating surfaces, but, if mixed with the soft carbonate scale, they tend to make it hard and dense, a good insulator against the conduction of heat and difficult to remove.

Doctoring the Water

From the foregoing it is evident that water which is either dirty or hard is likely to give the boiler stomach trouble and the cure for this indigestion is to make the water digestible. But "What to do?" Before trying to treat any water, we should know what is in it. There may be a lot of things, depending on where the water comes from, but for our purposes we can lump them under a few heads.

First, dirt, suspended matter of all kinds, which can be seen floating in the water and can be taken out by straining and filtering. If the water is dirty with no hardness, the filtering is easy, but a small amount of dirt does no harm except to cause some mud in the bottom of the boiler, and this can be cleared out by blowing down as often as may be needed. Second, hardness, or, as it is sometimes called, alkalinity. This is produced by the materials already mentioned and is the stuff which causes scale in the boilers. Third, acids; and fourth, oils and greases.

We need to make a reasonably accurate test of the water for all these before we know what to do, and if the water comes from a river into which sewage is dis-

charged, reasonably frequent tests should be made, because the material in the water may change from day to day. The easiest way to determine suspended matter is to take a gallon of water, pass it through filter paper and see what you get. If any considerable amount of suspended matter is found, it is a sure sign that the water ought to be filtered.

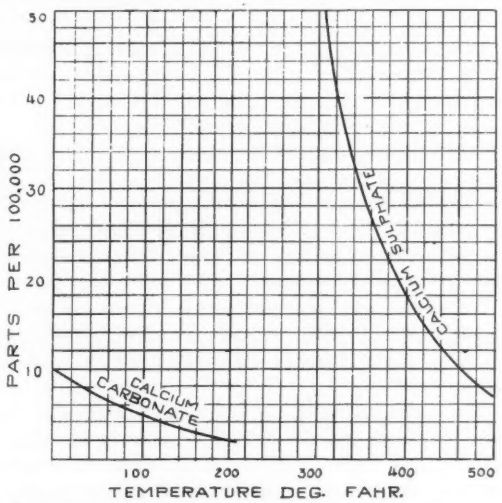


FIG. 1. EFFECT OF TEMPERATURE ON SOLUBILITY OF CARBONATES AND SULPHATES

Frequently alum (aluminum sulphate) is used in the treatment of water, particularly for city supplies to hasten the coagulation of the suspended matter. This will give a means of forming calcium sulphate in the water as it furnishes the agent for changing calcium bicarbonate to calcium sulphate; in this way, temporary hardness is changed to permanent hardness. Water which has been treated with alum should, therefore, be carefully tested in this regard, and if it is found that there is more calcium sulphate in the water in the boiler than before the alum treatment, it may be better for the power plant to filter its own supply and avoid the alum treatment. Another possible effect of the alum treatment is that if no lime is present in the water, sulphuric acid may be released, leaving a corroding element in the water.

When we start to treat the water with re-agents in order to remove the hardness, we need to know accurately just how much hardness there is, in order to use the right amount of re-agents, yet not too much. For not only do these chemicals cost money, but using too much may introduce materials into the boiler which are almost as undesirable as the original hardness.

Soap Test

Having filtered the water, we can go ahead with our examination to find out what else ails it. First to find the hardness, what is known as the "soap test" is the simplest and most common. We use soap, when washing, to cure the hardness in the water and we cannot get a good lather until we have killed all the hardness. The amount of soap necessary to use in order to get a lather indicates how much hardness the water contains. That's the whole story of the test; but in order to know how much re-agent to use, we must go rather carefully. First, we must have a standard soap solution, and we get it this way: Dissolve 13 grams of sodium oleate in 500 c.c. of 96 per cent alcohol and add 500 c.c. of water. This ought to give the right strength, but the sodium oleate may vary somewhat, and to make sure, it is best to test out the soap solution with a standard hard water. Don't get scared at these chemical names. The materials are quite harmless and you can get them at any drug store without a prescription; and you don't have to be able to call them by their names in order to get them to work.

Standard hard water is made by dissolving 1.11 grams of calcium chloride in 1 liter of distilled water. Now to test the soap solution we measure 58.3 c.c. of pure distilled water into a bottle, put into it 12 c.c. of the standard hard water. Then from a measuring tube add soap solution, ½ c.c. at a time, shaking the bottle well after each dose of the soap solution. The hard water is neutralized when a lather is formed about ¼ in. deep which will last for 5 min. with the bottle lying on the side.

It should take 13 c.c. of the soap solution to do the trick. If less is required, it indicates that the soap solution is too strong and should be diluted with pure distilled water until it takes exactly 13 c.c. of the soap solution to give the permanent lather; and if neutralizing takes more than 13 c.c., it will be necessary to dissolve a little more sodium oleate in alcohol and put it into the soap solution.

Standard soap solution if kept from the air will remain in good condition from five to six weeks. If

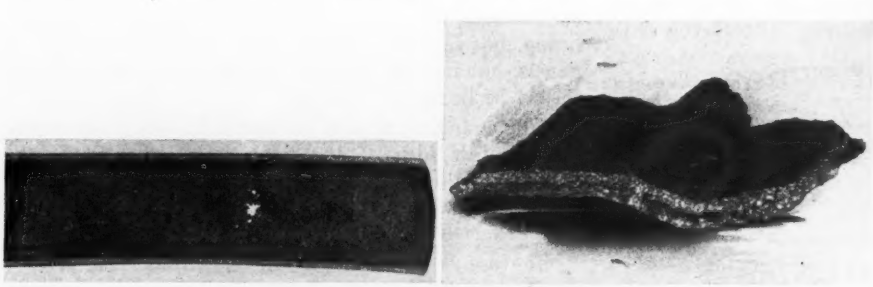


FIG. 2. CORROSION OF TUBE, AND CRYSTALLIZATION FROM OVERHEATING

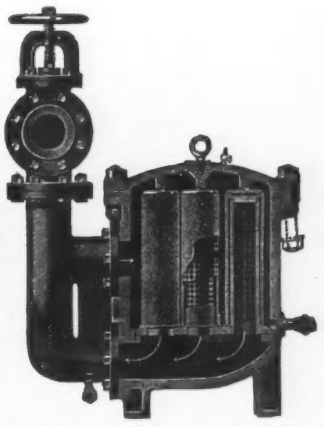


FIG. 3. MULTIPLE FEED WATER FILTER

kept longer it may absorb impurities, particularly if there is considerable air in the top of the bottle in which it is kept, and it should be tested out with standard hard water before using to test raw water.

For raw water the soap test is exactly the same as the neutralizing of standard water except that we find

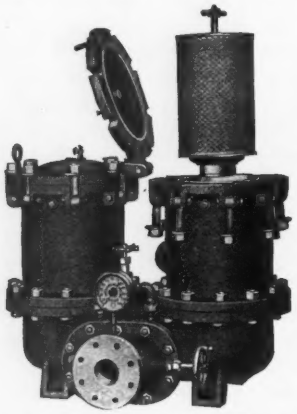


FIG. 4. TWIN STRAINER AND GREASE REMOVER

how much of the standard soap solution it takes to neutralize the hardness in 58.3 c.c. of raw water. Then the number of cubic centimeters of soap solution required to give the permanent lather is equal to the grains per gallon of hardness.

This term "grains per gallon" is the way the chemists talk about the hardness of water but for the engineer it is rather more convenient to talk about the number of parts per 100,000, and the grains per gallon multiplied by 1.714 will give the parts per 100,000; that is, a hardness of 16 grains per gallon means that there will be 16 × 1.714 or 27.42 lb. of scale-forming material per 100,000 lb. of water. This doesn't sound like a lot when you say it that way, but if you have

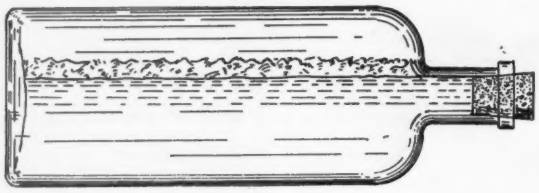


FIG. 5. SOAP TEST

a 1200-hp. boiler operating with a water of 16 grains per gallon hardness, you will get 263 lb. or 2½ cu. ft. of scale-forming material dumped into that boiler every 24 hours, which is some rock pile.

If, in making the soap test, a hardness of more than 14 grains per gallon is shown, it will be necessary to re-test, diluting a fresh sample of raw water with its own volume of distilled water. Test out this diluted sample by the same soap test and multiply the result by 2. The reason for this is that after enough soap solution has been added to neutralize more than 14 grains of hardness, there will be so much alcohol in the resulting mixture that a permanent lather cannot be secured. Also note that a scum formed on the surface, the water remaining clear, is not lather; when the true lather is formed the water will be milky in appearance.

If this soap test shows less than 8 grains per gallon hardness, the water may be classed as soft and will be very good for boiler feed, barring the discovery of acids, oils and grease by later tests. If it shows from 8 to 12 grains per gallon, it will be good; from 12 to 15 fair, and from 15 to 20 poor. These last three classes would be noted commonly as hard water. Anything above 20 grains per gallon may be considered as very hard and also very bad for a boiler. With anything over 10 grains per gallon, it is desirable to treat the water in some way.

Test for Alkalinity

Next we want to know whether the water is alkaline or acid.

Either acids or strong alkalis may be injurious in boilers, the latter by causing iron plates to become brittle through an action not well understood and the former by causing corrosion. We must test for both. For the alkalis we need two test solutions. First, dissolve one gram of methyl-orange powder in 1000 c.c. of distilled water. Second dissolve 40 c.c. of standard hydrochloric acid in 1000 c.c. of pure distilled water and label the bottle in which you keep this latter "Standard Acid N-5." Put 200 c.c. of the water to be tested in a white porcelain dish; then rinse out the measuring flask with distilled water and pour the rinsings into the dish. Now add two drops of the methyl-orange solution and the water will turn a lemon yellow. Next add hydrochloric acid solution drop by drop from a measuring tube, stirring constantly with a glass rod until the color changes to a faint pink. The number of cubic centimeters of the hydrochloric solution used for this purpose gives the number of parts of calcium carbonate per 100,000. One of the most common forms of calcium carbonate is limestone or marble and when you get a calcium carbonate scale in your boiler you are giving it a marble lining, not so dense as that used for your switchboard panels, but not the kind of material with which boilers should be lined.

In passing, it should be noted that this test really gives a fair idea of the temporary hardness in the water. If this be subtracted from the total hardness as shown by the soap test, it will give an approximation of the permanent hardness or sulphates in the water.

In case it happens that the alkalinity test gives a result higher than the soap test, there is probably sodium bicarbonate or soda ash present, and the water should be given a careful chemical analysis. This excess of soda ash is likely to cause foaming and under the influence of heat and pressure may release sodium hydroxide which in time has an embrittling effect on the boiler plate.

Test for Acid

Now to find out whether the water can eat steel. First to make our test solution; dissolve ½ gram of phenolphthalein crystals in 100 c.c. of 95 per cent alcohol and add caustic soda slowly, stirring the solution constantly until the faintest pink color is obtained. Second, dissolve 21½ grams of pure carbonate of soda in 250 c.c. of hot distilled water, and add to this cool distilled water to make 1000 c.c. Put this in a bottle and label it "Standard Alkali N-5."

To test the raw water for acidity put 200 c.c. in a porcelain dish and add two drops of phenolphthalein solution; then add the sodium carbonate solution drop by drop from a measuring tube, stirring constantly, until a deep pink color remains permanently. The number of cubic centimeters of the alkali solution used, multiplied by 9.58, gives the parts of acid per 100,000 in the raw water.

If the tests show more than 17 parts per 100,000 of alkalinity, it is an indication that the water should be treated before going into the boiler, as the accumulation of scale will be too rapid to be counteracted effectively by blowing down and tube cleaning. Water which shows over 7 parts per 100,000 of total hardness should be treated in some way, as otherwise hard scale will form rapidly. If any acid whatever is shown, the water should be treated to neutralize this before it is allowed to pass to the boiler.

Sulphates

Some other tests are desirable for minor impurities and for quality. A snap test for calcium sulphate may be made by putting 2 in. of boiler feed water in a test tube and adding a little barium-chloride solution. This will give a white precipitate and if this precipitate remains in suspension after a little nitric acid is added, it shows that calcium sulphate is present in fairly large

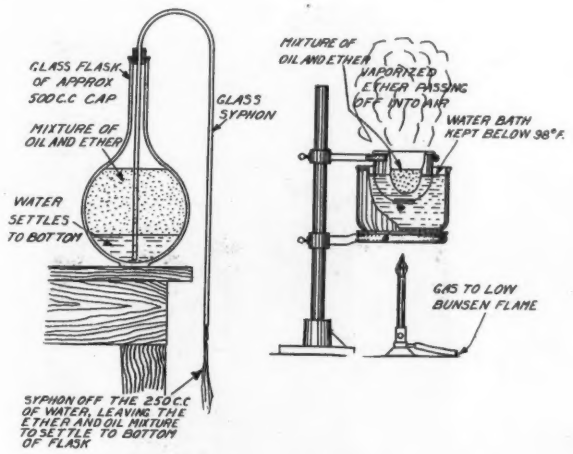

GLASS FLASK OF APPROX 500 C.C CAP
MIXTURE OF OIL AND ETHER
WATER SETTLES TO BOTTOM
GLASS SYPHON
SYPHON OFF THE 250 C.C OF WATER, LEAVING THE ETHER AND OIL MIXTURE TO SETTLE TO BOTTOM OF FLASK
MIXTURE OF OIL AND ETHER VAPORIZED
ETHER PASSING OFF INTO AIR
WATER BATH KEPT BELOW 98°F.
GAS TO LOW BUNSEN FLAME

FIG. 6. TEST FOR OIL AND GREASE IN WATER

quantities and will form a nice thick coat of hard, fine-grain scale.

Magnesium and Chlorides

When found in boiler feed water in any considerable quantity, this causes foaming. To test for it, put 3 in. of the water in a test tube and bring to a boil over a gas flame. Add a little carbonate of ammonia and a bit of phosphate of soda. Let the solution stand a few minutes and if a white precipitate forms, magnesium is present and may very likely carry with it some chlorine which will cause corrosion. To test further for chlorides, dissolve 4.79 grams of silver nitrate in 1 liter of distilled water and place in a dark bottle. Next, dissolve 10 grains of potassium bichromate in 100 c.c. of water. Put 58.3 c.c. of feed water in a bottle that will hold about 100 c.c.; add a few drops of the potassium bichromate solution; then add silver nitrate solution, ½ c.c. at a time, shaking the mixture gently after each addition, until a permanent red rust color is obtained. The number of cubic centimeters of silver nitrate solution used multiplied by 1.714 will equal, approximately, the parts per 100,000 of chlorides present in the water. Over 5 parts per 100,000 denotes a serious condition.

Organic Matter

For organic matter a quick test is to put a few drops of strong solution of potassium permanganate in 500 c.c.

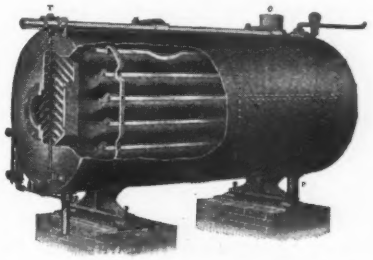


FIG. 7. HOT FEED WATER PURIFIER

of feed water and watch the color reaction. If the red color of the permanganate fades away leaving the feed water colorless, it indicates a large quantity of organic matter present. If a yellowish tinge remains in the water there is some organic matter present but not in large quantities.

Oil and Grease

To test for oils and greases, put 250 c.c. of cool water in a glass-stoppered bottle and add 50 c.c. of ether. Shake well and allow to stand for 15 min. If oil or grease was present, the ether will have dissolved it and the oil-ether mixture will float on the surface of the water. Siphon off the water from beneath; weigh a porcelain dish carefully, then put in the remaining mixture and evaporate the ether by placing the dish in a bath of lukewarm water. This will leave the oil or grease in the bottom of the dish. Weigh again and the difference will be the weight of oil and grease per 250 c.c. of water. Multiplying this value by 15.14 gives the amount of oil per gallon. Any amount which can be detected is undesirable and the water should be treated to remove it.

Causticity Test

Tests of the treated water should be made from time to time to check the correctness of the treatment. In addition to the ones already given, it is desirable to test for causticity as follows: Add 1 drop of phenolphthalein solution to 50 c.c. of the water to be tested and a pinkish color will appear. Add sulphuric acid, a drop at a time, and shake. When the color disappears, the causticity has been neutralized, and each 0.1 c.c. of acid used denotes 1.7 parts causticity per 100,000.

In properly treated water the tests should show a relation of alkalinity, hardness and causticity about as 6:5:4. If there is an excess of causticity, too much lime has been used; if an excess of alkalinity and low hardness, too much soda ash has been used; reverse results indicate the opposite faults.

Methods of Water Treatment

Trouble-making materials can be gotten out of water in one of four ways; for the suspended matter, straining, or filtering, through heavy cotton cloth stretched over cylinders or disks, this cloth being changed and cleaned periodically. For the scale-forming material a treatment with chemicals so as to throw down these solids in comparatively harmless form either in or outside of the boiler. For the acids and corrosive ingredients a neutralization with some form of alkali. Or we may get rid of all solids by evaporation and condensation which will leave the impurities behind, but will not eliminate the acids, so that separate treatment will have to be used to neutralize them.

In practical working out of these matters, we have several variations. To get rid of the scale-forming material, the water may be heated to 200 deg. for 15 to 20 min. and a large part of the carbonates will be thrown out in the form of precipitate. To have this thorough, however, time must be allowed to permit the solids to settle to the bottom of the vessel. The effect can be secured by keeping the water at the 200-deg. point and allowing it to travel slowly in thin films over pans or plates into which the scale may collect. Sulphates must be treated by changing them to a harmless form which will readily precipitate and for the cold process the carbonates may be treated in like manner.

POUNDS OF PURE RE-AGENT PER 1000 GALLONS OF WATER HAVING ONE GRAIN PER GALLON OF VARIOUS IMPURITIES

	Reagents	
Impurity	Soda Ash	90% Hydrated Lime
Calcium Sulphate	0.124	-
Calcium Carbonate	-	0.117
Calcium Nitrate	0.115	0.067
Calcium Nitrate	0.151	-
Magnesium Sulphate	0.140	0.098
Magnesium Carbonate	-	0.280
Magnesium Nitrate	0.115	0.067
Magnesium Chloride	0.180	0.123
Sodium Carbonate	-	0.093
Ferric Sulphate	0.126	0.074
Ferrous Sulphate	0.110	0.070
Ferrous Carbonate	-	0.169
Carbon Dioxide	-	0.240
Sulphuric Acid	0.171	0.100

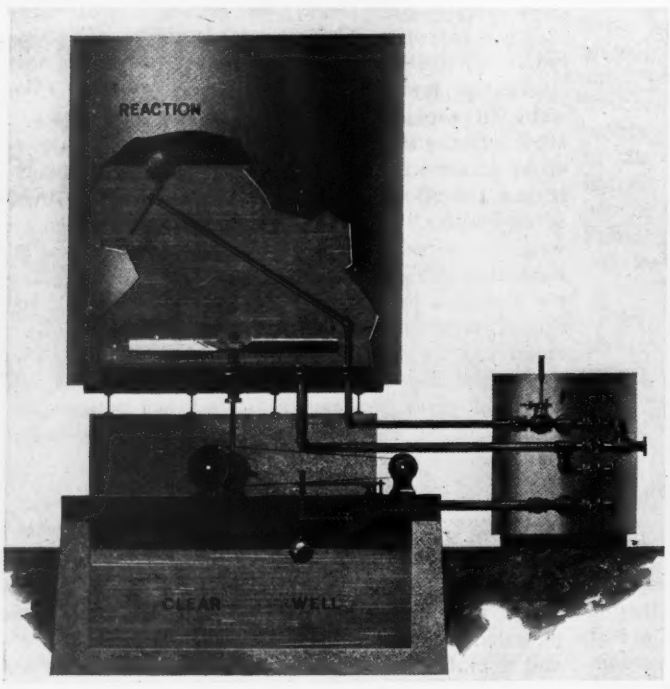


FIG. 8. INTERMITTENT COLD SOFTENING SYSTEM

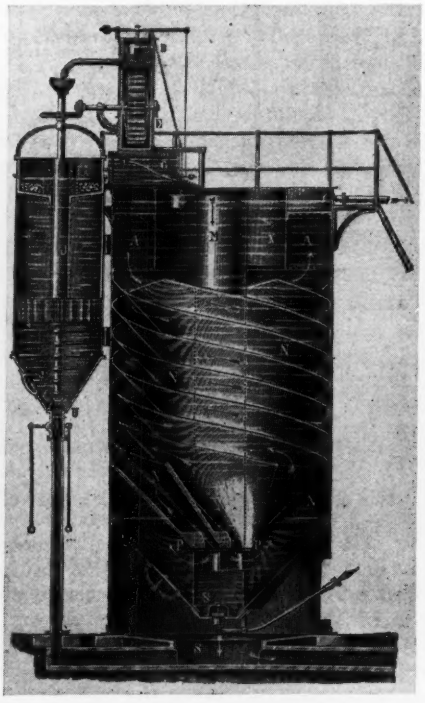


FIG. 9. SECTION OF CONTINUOUS COLD PROCESS SOFTENER

The usual chemicals are soda ash and lime and the amounts required for various degrees of hardness are as shown in the table herewith.

As given by the Hartford Boiler Insurance Co., roughly 1 lb. of soda ash per 10 hr. is needed by a 75-hp. return tubular boiler for ordinary water; 2 gages of water should be blown down each 12 hr. and the boiler emptied and refilled every two weeks. This proportioning is hardly accurate enough to be satisfactory, although it might serve as an index, temporarily, until accurate data for treatment can be obtained. Another rough rule is that one grain of soda ash is needed to neutralize one grain of sulphate, and one grain of caustic soda to neutralize one grain of carbonate.

Water will be satisfactory for boiler feeding, if it has been treated so that it has not over 1½ grains hardness, zero causticity and 1½ grains alkalinity per gallon.

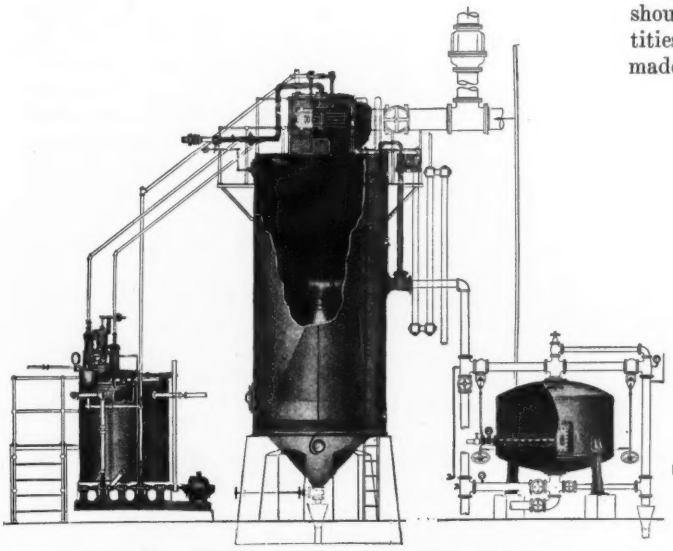


FIG. 10. TYPICAL CONTINUOUS HOT PROCESS SOFTENING AND FILTERING SYSTEM

the reagents are being properly proportioned as the impurities in the raw water may change from time to time. Within a range from 7 grains of alkalinity to 12 grains of free sulphuric acid a sample of water should be tested every day. If there are greater quantities of alkalinity or acid than this, tests should be made more frequently.

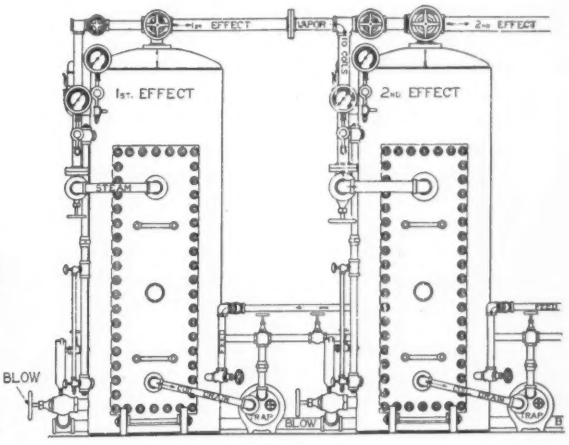


FIG. 13. EVAPORATOR PLANT FOR FURNISHING DISTILLED FEED WATER

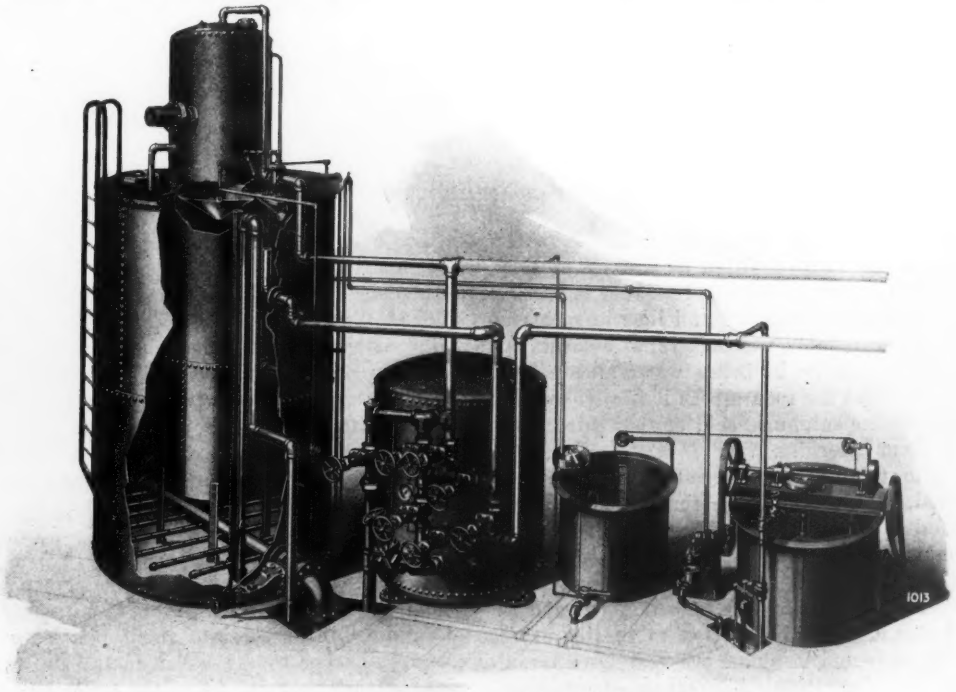


FIG. 11. INTERMITTENT HOT PROCESS SYSTEM

This would imply no waste of chemical reagents and is practically an impossibility but it gives us the right mark to shoot at.

In treating water it may be done by the cold process, either intermittent or continuous, or by like hot processes as described by Mr. Joos in a preceding article.

Samples of the raw water and of treated water should be tested from time to time to make sure that

In connection with the degree to which it is desirable to reduce hardness of water, if a boiler is forced at a high pressure, much softer water is needed than for a boiler running at comparatively low pressure, at or under rating. For instance, a 500-hp. boiler using water carrying 15 grains of incrusting solids per gallon when forced to 750 hp. will take in as much scale-forming material as it would when run at normal rating and using water carrying 22½ grains of hardness. The high

pressure increases trouble because of the increased tendency of the scale to bake on to the boiler surfaces.

Compound Treatment

Plants for softening water and removing the precipitate outside the boiler require considerable space and are rather expensive; for this reason the treatment of water before the water enters the boiler to reduce the permanent hardness to temporary hardness, then allowing the deposit to take place inside the boiler and blowing out the soft deposit, is often practiced. This process is usually known as "boiler compound treatment" and is satisfactory where the compound is fitted to take care of the impurities in the water.

Careful analysis of the water should be made before adopting any form of treatment, but it so happens that the majority of the impurities found in ground water taken from wells or from streams which do not carry sewage are confined to the carbonates and sulphates of calcium, sodium and magnesium in varying quantities. and may result in a dense water which will produce bad foaming. It should also be remembered that, if boiler compound is introduced into the water before it goes to a closed type feed water heater, incrusting solids will be deposited in the heater and in the piping leading from heater to boiler, so that in time the heater and the piping will have their operation seriously impaired. The heater can be blown down more or less frequently but the piping cannot, and it is better, if the compound method of treating water is used, to arrange the treatment so that, so far as possible, the precipitates will be thrown down where they can be regularly cleaned out.

Zeolite

Zeolite treatment is a special form of the reagent method. This consists in passing the water over the zeolite, transferring sodium from zeolite to the water and taking out calcium and magnesium salts. If there is a large amount of hardness in the raw water, the

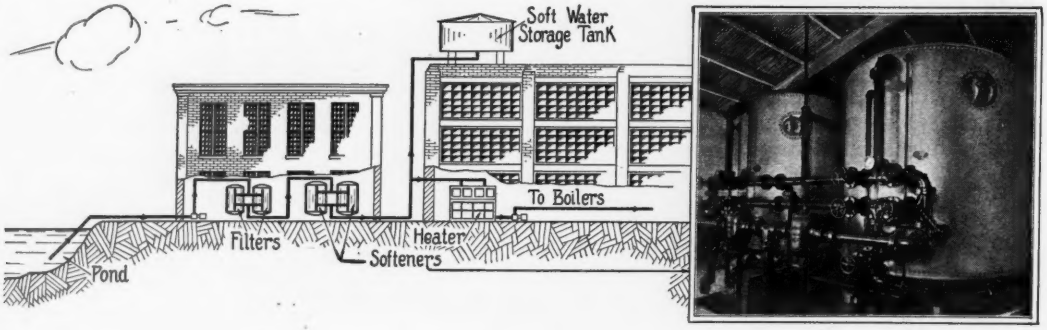


FIG. 12. ARRANGEMENT OF APPARATUS FOR ZEOLITE TREATMENT

As shown by the table previously given, all these can be reduced to a harmless condition by the use of varying amounts of soda ash and lime. Hence, it is possible to make up a mixture of soda ash and lime in such proportions as will reasonably well neutralize a large percentage of the impurities in boiler waters taken from these two sources and the soda ash as indicated can also be used to neutralize sulphuric acid or the hydrochloric acid formed from chlorides.

In order to treat water successfully by the compound method, there should be a thorough mixture of the compound with the water. Preferably, the compound should be fed continuously, but satisfactory results can be obtained by feeding compound periodically at rather frequent intervals. The amount of compound used should be in proportion to the impurities in the water, as insufficiency of compound will result in annoying scale-formation while excess of compound will result in a surplus of sodium carbonate in the boiler causing foaming and possibly the production of caustic soda. In case a boiler is badly scaled it is well to remove this scale before beginning the use of boiler compound.

It is possible to soften water so that it will contain not over 2 grains per gallon of incrusting solids and 1½ grains of soluble salts of calcium and magnesium; but it should be remembered that when using water so softened, unless the boiler be blown down with reasonable frequency, the soluble salts will become concentrated zeolite will produce a large amount of sodium salts in the treated water. This will give a dense water in the boiler and will call for blowing down and emptying and refilling as may be necessary. Zeolite will give water of zero hardness and automatically takes care of variation in the hardness of the raw water, but it requires special pretreatment with lime if the water contains acid. Also the presence of carbon dioxide is not affected, nor is the oxygen removed, so if these are present special treatment is necessary in addition to passing the water over the zeolite.

Mechanical Scale Prevention

Incrusting materials in the boiler can be prevented from doing any serious harm, if a treatment is given to render the scale into small pieces and prevent it from adhering to the boiler plate. In such cases the scale is easily carried out of the boiler by blowing down. To prevent adhesion, various forms of chemicals, known under the general name of boiler metal treatment, are in use and also the method of introducing finely divided graphite. The action of both systems seems to be that the chemical or the graphite, carried by the circulation of the water, penetrates the cracks and pores of the scale and between the scale and the metal, causing a separation which is accelerated by the heating and cooling of the boiler during operation. Also a thin film of the metal treatment or the graphite adheres to the metal surfaces, thus preventing adhesion of further

scale. Incrusting material will, of course, be precipitated in the boiler and must be removed by blowing down; but if this be attended to regularly and with the required frequency, the boiler surfaces can be kept clean and the water kept at a density sufficiently low to avoid difficulty from foaming and priming.

Evaporators

Use of evaporated water is comparatively recent and is, ordinarily, in connection with the re-using of condensate. Returns from the condenser form the greater part of the boiler feed and only such make-up water as is required has to be furnished by the evaporators. It has sometimes been found that when using this method there was considerable scale-formation but investigation showed that the difficulty was from leakage in the condenser, so that a considerable amount of the raw cooling water became mixed with the condensate and, as the condensate was not treated, whatever scale-forming materials were brought in by the raw water were carried into the boiler. If the raw water available is fairly clear of impurities, it may be found more economical to use a barometric or jet condenser, take the feed water needed from the discharge of this condenser and treat it all by a softening process, thus avoiding the possibility of any untreated water getting into the boiler.

Removal of Sediment from Boilers

Removal of Precipitate as It Is Thrown Out of Solution in the Boiler Water Reduces Scale Formation

IN AN EFFORT to reduce the amount of scale formation on boiler-heating surfaces much may be accomplished by removing as much as possible of the scale-forming material before it has had a chance to adhere to the walls of the tubes, that is, after it has been precipitated out of the boiler water.

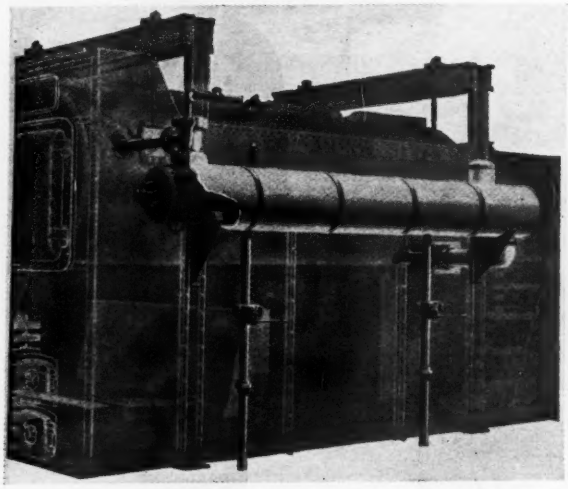


FIG. 1. CONTINUOUS BOILER FEED PURIFIER

This at once suggests that there be a place provided in the boiler, away from contact with that hot furnace gases, where this settling out may be allowed to take place, where it will do the least amount of harm. This localizing of deposits is provided for in most types of boilers by a mud drum from which the newly accumulated soft scale may be readily blown out at frequent intervals. All scale-forming material is not heavier than water, consequently it will be found that some collects on the surface of the water where it may cause foaming. This material may be disposed of by means of a surface blowoff or skimmer.

In Fig. 1 is shown a feed water purifier. It is essentially an external mud drum. Where the feed water is heated to the boiler temperature and scale, insoluble in water of this temperature is thrown down. The operation is simply this: The feed water from the pump enters through a check valve at the top of the mixing chamber, shown at the left end of the shell, through a nozzle inlet, causing a syphoning effect which induces a flow of hot water from the boiler. The feed and hot water from the boiler mixes at this point and is discharged upon the baffle plate, which extends across the shell directly below the inlet and directs the flow against the left end of the shell, causing the water to spread and enter the purifier quietly and with low velocity. When the feed pump is inoperative, the water in the boiler, having a higher temperature than that in the purifier, causes a natural circulation through the purifier which can be regulated by a valve in the return line.

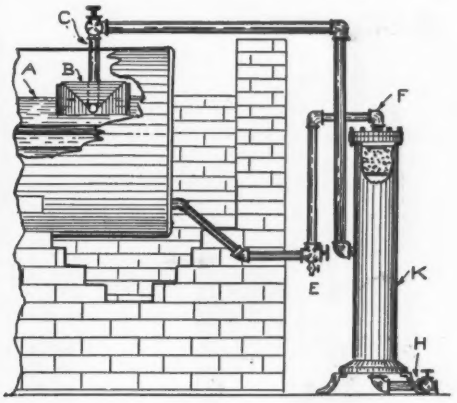


FIG. 2. SCALE-FORMING MATERIAL IS REMOVED FROM THE BOILER WATER AS IT CIRCULATES THROUGH THE CLEANER

As the water in the purifier is at a lower temperature than the incoming feed, the flow through the purifier is principally at the surface. The water below is quiescent and the impurities in suspension are allowed to concentrate quietly. At the end of the travel through the unit the circulation meets the resistance of another baffle placed in front of the discharge pipe at the right end. This discharge pipe has an internal extension which extends almost to the top of the shell, thus maintaining the water level at this height. The sludge thrown down by the water in its passage through the apparatus collects at the bottom of the shell from whence it is blown off.

Surface water in the boiler may be circulated and freed of its suspended matter by means of the apparatus shown in Fig. 2. The skimmers, B, are so located that the inlet is about 1 in. below the average water line. Surface water enters the funnel and rises through

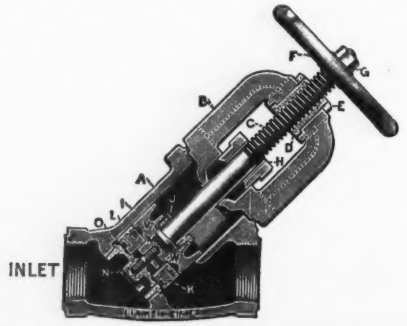


FIG. 3. SECTION OF STRAIGHTWAY BLOWOFF VALVE

the pipe, C, whence it is carried to the vertical filter cylinder, K, which it enters at about the mid point. The velocity of flow here is low and any suspended material is allowed to settle in the dead water space at the bottom, from where it may be blown off through the blowoff line, H. In passing back to the boiler the water rises in the cylinder and passes through filtering material at the top; thence it passes through the line, F, back to a point near the bottom of the boiler. Circulation is established and maintained by a difference in head occasioned by the difference in temperature of the water in the boiler and in the cleaner.

Where boiler plants are located in populated districts, the blowoff must be discharged to the sewer. In most communities there is an ordinance prohibiting a direct discharge and in such cases blowoff tanks are necessary. Such a tank is merely a reservoir into which the blowoff water is discharged and there allowed to cool before being emptied into the sewer. Its capacity should be sufficient to accommodate, say, one gage of water from each boiler that is to be blown down at the same time. As a matter of safety, its construction should be such as to withstand full boiler pressure. Normally it will be subjected only to atmospheric pressure as the discharge side is always open, but it is within the bounds of possibility that the discharge line may become clogged with scale in which case full boiler pressure will build up within the tank.

Blowoff Valves and Cocks

To prevent excessive erosion of blowoff valve seats and discs caused by the foreign material in the water, blowoff lines are almost always provided with a cock in addition to the valve. In operation the cock is opened last and closed first. In this way, there is of course no flow while the main valve is being opened or closed, consequently there is but little danger of particles of scale cutting the seat. It is of importance that the blowoff valve be perfectly tight when not in use because great quantities of heat may be lost in this way without the knowledge of the operator.

Figure 3 shows a section of a Y type reversible disc blowoff valve. This valve should be used with a cock as corrosion is likely to groove the seat so that it leaks.

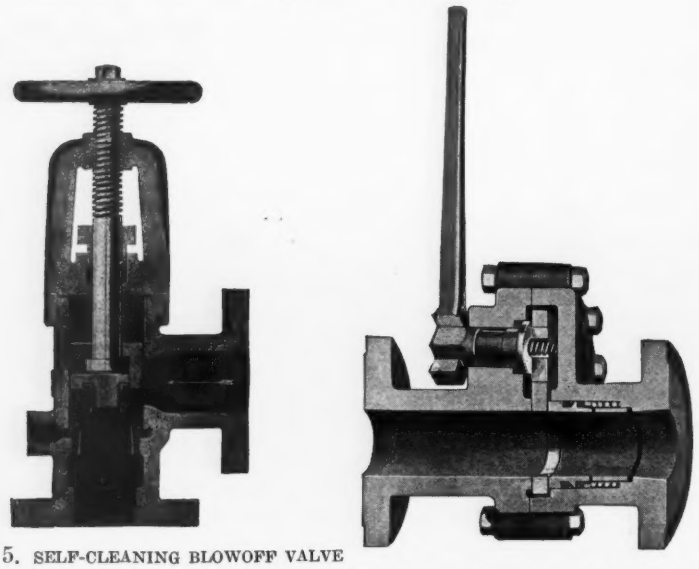


FIG. 5. SELF-CLEANING BLOWOFF VALVE

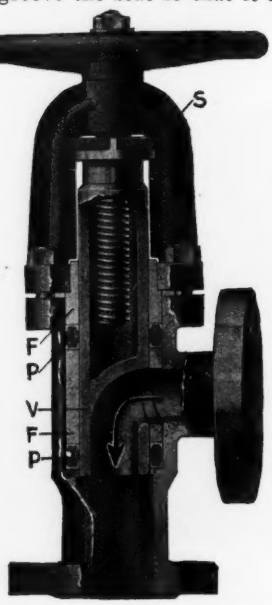


FIG. 6. SEATLESS BLOWOFF VALVE

FIG. 4. LEVER OPERATED SWING GATE TYPE BLOWOFF VALVE

In Fig. 4 is shown double tightening valve of the lever operated swing gate type. The seat is self-grinding and the construction is such that scale cannot cut across the seat to injure it. Figures 5 and 6 illustrate two types of valves that may be used without a separate cock. The valve shown in Fig. 5 is provided with a plunger backing the disc which acts as a cock in reducing the flow to a negligible amount before the disc seats. The valve shown in Fig. 6 is a so-called seatless valve. It consists of a plunger which, when in the lowered position, cuts off the flow and presents a steam-tight joint. When raised, a port through the plunger wall registers with that in the valve body and a passage is opened to discharge. Scale particles cannot come in contact with the seating surfaces and hence it can well be used for blowoff service without a separate cock.

Boiler Tube Cleaners

Scale-Free Heating Surfaces Are Essential to Efficient Operation

TO INSURE the economical generation of steam it is of the utmost importance that the heating surfaces be kept clean—free from scale and soot accumulations. Aside from this point of view, there is another of equal if not greater importance and that is safety. Scale deposits offer a tremendous resistance to the flow of heat through boiler tubes and shells and as a consequence there is a liability of overheating which may cause an explosion. Such an occurrence is to be avoided at all costs. It endangers life, the value of which it is impossible to compute, and also property, which has a more tangible value. From a business standpoint, however, the loss of efficiency should receive attention.

It has been estimated that scale offers a resistance to the transfer of heat 100 times that of iron of equal

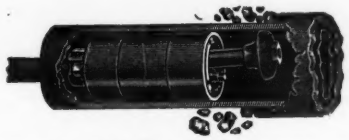


FIG. 1. VIBRATOR CLEANER FOR REMOVING SCALE FROM RETURN TUBULAR BOILERS

thickness. To produce equal steaming capacities, tubes with 1/16 in. scale will require about 15 per cent more fuel than clean tubes; ⅛ in. scale, about 25 per cent more fuel; ¼ in., about 40 per cent; and ½ in, about 70 per cent.

There are various means employed to free a boiler of scale. One is the use of compounds in the boiler itself to change the character of the material that is precipitated as the water in the boiler is evaporated.

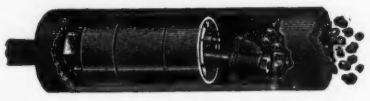


FIG. 2. VIBRATOR CLEANER WITH CUTTER HEAD FOR FIRE TUBE BOILERS

If the particular compound used is adapted to the feed water that is employed, the results will be favorable. Another means is the use of external water treating apparatus. With this treatment the character of the hardness producing substances is changed and some of it is precipitated before the water is introduced into the boiler. Much of the scale that is formed in a boiler is first precipitated in the form of a sludge or mud which may be removed through either the surface or bottom blowoff. All of these methods are valuable in that they reduce the rate of formation, but unless chemically pure, distilled water is used for boiler feed purposes, scale is bound to accumulate. When such scale has formed its removal can probably be best accomplished by the use of some kind of mechanical tube cleaner.

While there are many ramifications in the detail of design of mechanical cleaners, they may be divided into two general classes; those that loosen the scale by vibration and those which cut it out with a cutter. The former is applicable to either water tube or fire tube boilers, the latter only to the water tube type.

Vibrator Type Tube Cleaner

Vibrator cleaners may be classified as to the motion used. In one type the vibrator head is moved diametrically across the tube. The arm carrying the head is pivoted near one end. Pivoted on this arm between the fulcrum pivot and the head is a piston working in a cylinder diametrically across the body of the instrument. Ports to the cylinder are controlled by a slide valve actuated by the end of the arm on the opposite side of the main pivot. The action is similar to that

FIG. 3. ROTATING CUTTER CLEANER FOR STRAIGHT TUBES

of a simple slide valve engine. Vibrators having this motion are shown in Figs. 1 and 2. In this type the direction of the blow is normal to the wall of the tube. The force of the blow is not great, the work done per impact being of the order of about 2 or 3 ft. oz.; the effectiveness lies rather in the great number. These cleaners operate at the rate of from 3000 to 10,000 vibrations per min., the desired rate being governed by the thickness of the tube, and controlled by the pressure that is applied to the mechanism. The theory of the action is this, that the tube being made of iron is elastic and can be made to vibrate, while the scale is not elastic and will not vibrate. If the tube vibrates and the scale does not, there is a stress produced at the point of contact, the two are separated and the scale breaks away.

In the other type the motion is rotary, being produced by either a turbine or rotary steam engine. The vibrator head is fitted with an eccentric lug which is thrown, by centrifugal force, against the tube. As the head is at the same time rotating, the direction of the blow is tangential rather than normal as in the case of the first mentioned type. In any of the types mentioned the motive power may be furnished by either steam, compressed air, or water pressure. The question as to which should be used depends on what is most easily available in the plant and also on the type of boiler that is to be cleaned.

General instructions as to the operation of these cleaners may be summarized briefly as follows: Boilers should be cleaned whenever the scale accumulation has

reached a thickness of about 1/16 in. For safety's sake and for ease of operation, place a long, substantial platform in front of the boiler, on which to work. Don't allow the vibrator to strike within about 2½ in. from the end of the tube. See that the cleaner is the correct size for the tubes. Don't clean the outside of the tubes on a return tubular boiler until the soot deposit has been removed from the inside. Don't clean the tubes too fast. Keep the machine well lubricated, using a good grade of cylinder oil. Use sufficient pressure to give the desired rate of vibration. Keep the cleaner constantly in motion. If air is used, clean the boiler when cold; if steam, clean when hot, preferably

FIG. 4. CUTTER CLEANER IN OPERATION ON A HORIZONTAL WATER-TUBE BOILER

as soon as it is emptied. When cleaning water-tube boilers, don't crowd the hammer onto the scale. Keep the guard of the vibrator just back of the scale so that it taps on the bare tube. If the machine sticks as it proceeds, draw it back a few inches and get a new start. In using the transverse vibrator, it is essential to keep the head turning about its own axis so that successive vibrations will not be in the same plane. In the rotary type, this action is automatic and need not be considered.

For cleaning return tubular boilers, the head used serves only as a hammer and is of the form shown in Fig. 1. The head used for cleaning water-tube boilers has in addition a cutting edge such as shown in Fig. 2.

Cutter type cleaners are of the rotating type, being driven by either a small turbine or rotary engine. A view of one type rotating cutter is shown in Fig. 3. The rotating shaft carries at its extremity a spider having two, three, or four arms. On the extremities of this spider are pivoted the spider arms. The star shaped cutters are carried on a steel pin, about which they are free to revolve, on the opposite end of the arm. In operation, the arms are free to swing out to the full diameter of the tube, bearing out under the action of centrifugal force, but being free to yield should a constricted portion of the tube be encountered. There are two separate sets of cutters, the forward set are of the cone pattern so as to be able to work into thick scale; the rear finishing cutters are separate star shaped wheels. Such a cutter is shown in operation in Fig. 4. In principle the action may be compared with that of the tool used for dressing down grindstones and emery wheels. Where extremely heavy accumulations are encountered an additional drill head is sometimes used.

Water under pressure is perhaps the source of power most frequently used for cleaning water tube boilers because it is also made to serve to wash away

FIG. 5. CLEANER FOR CURVED TUBES PROVIDED WITH UNIVERSAL JOINT

the scale as it is loosened. Where either air or steam is used as the motive power, it is necessary also to supply a separate stream of water for this purpose.

Where straight tubes are to be cleaned and where more than the usual amount of power is required for the operation, this power may be supplied from an external source separate from the cutter head. The head is driven by means of a square shaft which is in turn operated by a rotary type engine. This engine is supported by block and tackle from a trolley extending across the top of the boiler. The engine is of course much larger than one that could be inserted into the tubes and the power output is proportionately larger.

In cleaning such boilers as the Stirling, for instance, where the tubes are curved, the ordinary type of solid shaft cutters cannot be used; it must be flexible so as to be able to pass around the curves in the tube. For this purpose, the tool is provided with a universal joint and the motor casing is relieved somewhat back of the forward bearing surface as shown in Fig. 5. Scale deposits are frequently heaviest at the bends and it is also here that there is a tendency for the motor casing to work over the scale before it has been completely removed. For this reason special care should be exercised at these points. In the past it has been necessary in cleaning this type boiler, for the workman to crawl into the drum to feed the cutter into the tube. This job was anything but a pleasant one. The space is small and stuffy and it was necessary to work in a cramped and uncomfortable position. As a result there was a tendency to rush the job in order to get it over

as soon as possible, and the tubes were not thoroughly cleaned. To get away from this feature the device shown in Fig. 6 was brought out to enable the boiler to be cleaned from outside the drum. The apparatus consists of a carriage which rolls on the tube sheet, a tripod for clamping the shafting in the man-hole. Rollers, on which the cleaner hose travels are placed

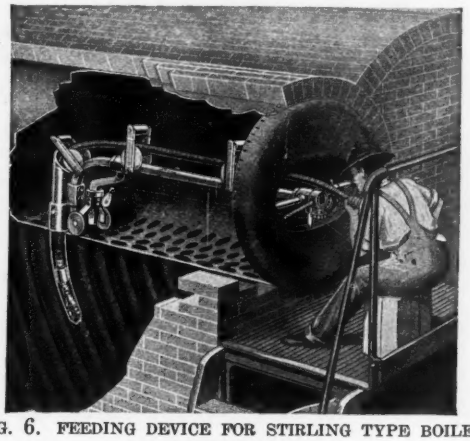


FIG. 6. FEEDING DEVICE FOR STIRLING TYPE BOILER IN OPERATION

at intervals along the shaft and a funnel on the carriage guides the cleaner into the tube. In addition to the added ease of operation, some time is saved because it is not necessary to allow the boiler to cool down before beginning the cleaning.

Boiler tubes are not the only kind of tubes that are subject to scale deposits. In addition there might be mentioned superheater tubes, economizers, condensers, and feed water heaters. To obtain the highest plant

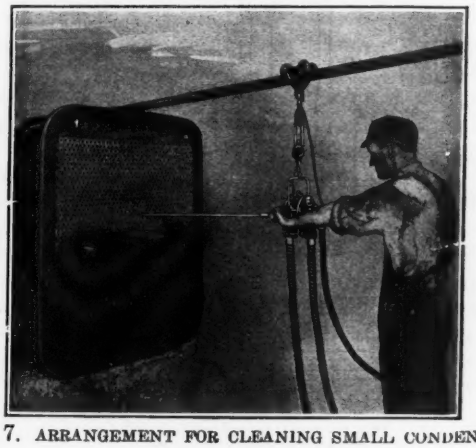


FIG. 7. ARRANGEMENT FOR CLEANING SMALL CONDENSER TUBES

efficiency it is just as important, perhaps, to keep these surfaces clean as it is to keep the boiler tubes clean. These surfaces may be cleaned in much the same manner as the boiler heating surfaces. Superheater tubes are of small section, usually not larger than 2 in., but they may be cleaned with a smaller size of the ordinary type cleaner. Economizer tubes are not likely to become incrusted with hard scale. What scale does form does not become baked hard but remains in a soft, spongy condition and can therefore be easily removed. The cleaner frequently used for this purpose is the type having an external motor driving the operating head through a long square shaft. The motor is supported on a tripod that rests on the upper tube sheet of the economizer.

Condenser tubes are frequently of quite small section so that it is impossible to use either the cutter or vibrator type cleaner. In such cases a drill is used, driven by an external motor, similar to the apparatus shown in Fig. 7. Wherever there is a heat transfer to water, scale is likely to form, and having formed, it reduces the heat transfer and consequently the efficiency of the apparatus. To secure the highest possible over-all plant economy, then, it is essential that all heat transfer surfaces be kept constantly in the best of condition.

Removal of Air from Feed Water

SEVERAL METHODS IN USE TO REDUCE CORROSION CAUSED BY DISSOLVED OXYGEN

THERE HAS been much interest during the last few years in the matter of corrosion where piping and boiler and economizer tubes and plates are eaten away internally by chemical action even though water is free from all impurities except gases absorbed from the atmosphere. It is now well known that this destructive action is due to the dissolved oxygen in the water and that it can be prevented if the oxygen is removed from the water.

For the removal of this dissolved oxygen two general methods have been developed both of which are in practical use. One of these is somewhat of a chemical nature and consists in the use of a degasifier which allows the water to come in contact with a mass of scrap iron or steel turnings. The oxygen attacks this scrap material, hence the water finally fed to the boiler is practically free of gas. Such a process is used in the Kestner degasser used mainly in Europe and the Speller process which is used in this country. This general method is employed in the Deactivator.

De-aeration by reducing the partial gas pressure and increasing the water temperature is the second scheme which is used. In Fig. 1 is shown a diagrammatic layout of one method used to accomplish this purpose.

Fundamentally the process employed consists of heating the water to its approximate boiling point and then injecting it into a chamber under a vacuum. Water enters from the supply mains and passes through one side of the circulating system of the heat exchanger. From the heat exchanger it passes, still under supply pressure, to the inlet valve of the heater and is admitted to the heater under the control of the water level float valve. Having been heated to the operating temperature of the heater, it passes under gravity head to the float controlled valve of the separator. In proper time it passes into the separator, gives up its dissolved air and the major part of the water passes on through separator to the boiler feed pumps. A small portion of the water is evaporated under the vacuum conditions of the separator and is withdrawn, mixed with air from the water, by the air ejector producing the vacuum.

This mixture of air, vapor and ejector steam passes to the other side of the circulating system of the heat

exchanger; the heat of the mixture is absorbed by the flow of the incoming supply water; the air escapes through the vent and the condensate returns by gravity to the heater.

There are various arrangements of the apparatus possible but the theory of the operation remains the same. The heated water is introduced into the separtor, which is maintained under vacuum pressure, the vapor pressure of which, by virtue of the vacuum, is

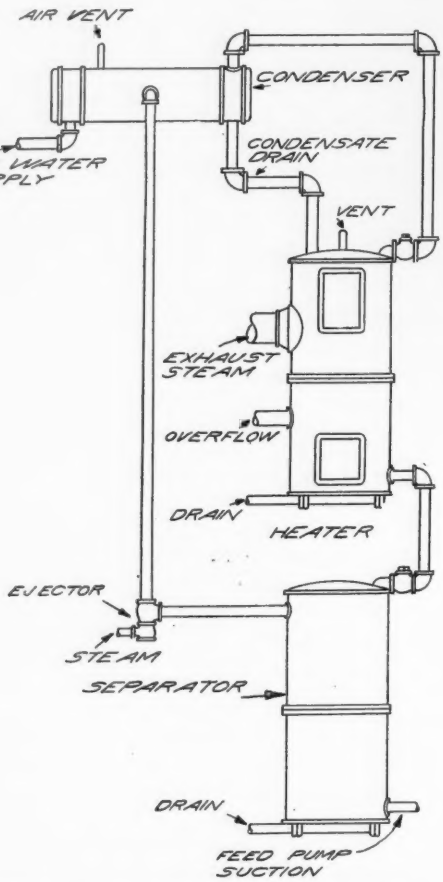


FIG. 1. HEATED WATER IS INJECTED INTO CHAMBER UNDER VACUUM IN THIS DE-AERATION PROCESS

appreciably lower than the vapor pressure of the heated water. Entering the separator at this low pressure, the water boils violently at the expense of the heat of the liquid until it comes into equilibrium temperature condition with the vacuum. In the process of explosive boiling, the steam bubbles form about the air bubbles as nuclei and remove the air when they pass into space.

In the operation of the process a drop in temperature of 22 deg. F. is arbitrarily given the water in the separator. This amount is given, as it proves a value upon which to figure with perfect safety, provided the initial temperature of the water entering the separator does not fall below 175 deg. F. Below this value it is impossible to give a special rule for guidance, although the process is workable. This, incidentally, gives an approximate temperature of 150 deg. F. for the water leaving the separator, and an economizer tube sweats at a temperature below 120 deg. F., so that there will likely be very few cases to which this rule does not apply.

Vacuum will always be equal to the atmospheric pressure minus the vapor pressure of the liquid at the temperature of the water leaving the separator. The amount of condensate is found by dividing the total

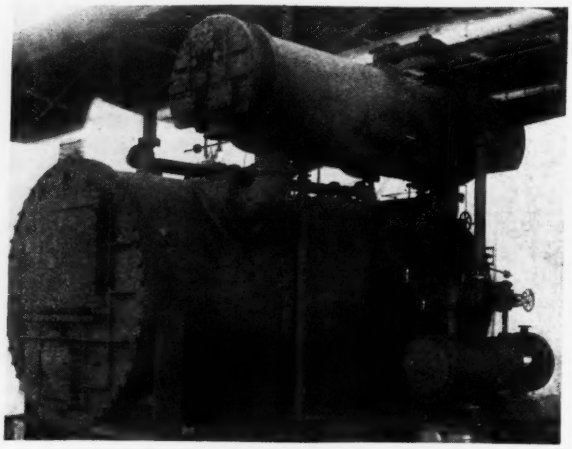


FIG. 2. ELLIOT DE-AERATOR AT THE DELAWARE STATION OF THE PHILADELPHIA ELECTRIC CO.

heat of the vapor at the initial temperature by the drop in heat content in the separator and multiplying by the total weight of the water. The heat abstracted by the separator and recovered by the condenser is equal

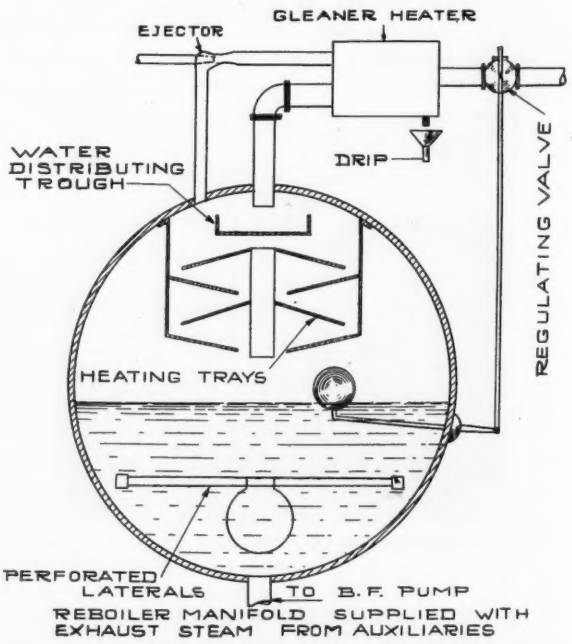


FIG. 3. OXYGEN FREE FEED WATER FURNISHED BY THIS COCHRANE DE-AERATING HEATER

to the drop in heat content in the separator and multiplying by the total weight of the water. The heat abstracted by the separator and recovered by the condenser is equal to the drop of heat content in passing through the separator, multiplied by the total number of pounds.

For operation under vacuum conditions a vacuum de-aerating heater as shown in Fig. 3 has been developed. The water to be de-aerated is first sprayed over trays and then falls into a storage space or pool. The steam used for heating the water is introduced through a perforated manifold at the bottom of the storage space. It bubbles up through the water in the storage space, carrying up with it any gases which may have been held either in solution or as small bubbles in the water. The steam then heats the water which is coming down over the trays, passing up through the trays counter-current to the flow of water and carrying with it non-condensible gases, which are withdrawn from the top of the tray stack by an air pump or ejector, the discharge of which is condensed in a small closed or tubular heater through which the cold water passes on its way to the de-aerating heater.

Vacuum is carried in the heater corresponding to the final temperature to which the water is heated and advantage can be taken of this vacuum in the operation of auxiliaries, such as house turbines, provided the latter are designed for vacuum operation and the exhaust steam piping system is tight.

If it is desired, however, to operate the auxiliaries under atmospheric pressure, while the water is to be delivered from the heater at a lower temperature, as at 140 deg. F., a flow valve is installed in the exhaust line. This acts as a dam, maintaining atmospheric pressure in the exhaust line and allowing steam to pass to the heater only when the pressure in the exhaust line tends to exceed a fixed minimum, as one or two pounds gage. With this arrangement the temperature of the water will vary, rising and falling according to the relative amounts of water to be heated and steam available. It therefore gives an automatic heat balance without the use of the usual automatic control devices, such as interconnection of the house turbo-generator with the main bus bars, automatic control of the steam supplied to the house turbine, etc. It is also possible to operate the de-aerating heater to deliver water at a fixed temperature.

By referring to Fig. 3 it will be seen that the steam enters the heater through a perforated manifold, while the boiler feed pump connection is at the bottom center. At the top are the ejectors, while the raw water enters through the large line at the upper center. The gleaner for removing the heat of ejector steam shows as the larger pipe section at this point. The water to be heated is fed into the heater through two top connections.

Plant Economy Demands Feed Water Heating

SAVING OF 10 PER CENT IN FUEL DUE TO FEED WATER HEATING EASILY POSSIBLE; TYPES OF HEATERS AND THEIR INSTALLATION

IMPORTANCE of the savings to be effected through feed water heating has become universally recognized in the power plant field although there are even yet many plants which do not take full advantage of such economies. Decrease in the fuel required for generating steam, increase in the steaming capacity of boilers, less severe contraction strains in the boiler and increase in over-all efficiency of the plant are points which have been reiterated time after time in order to bring out more strongly the advantages to be gained through the use of such equipment.

It is usually stated that there is a gain in fuel efficiency of 1 per cent for every 10 deg. F. that the feed water is heated. Although this is approximately correct, the only way to calculate the saving is to take the heat increment per pound from the initial temperature of the feed water to the temperature of the delivered product, whether that be wet or superheated steam.

When dry saturated steam is generated the following formula may be used.

$$\text{Per cent Saving} = 100\frac{t_2 - t_1}{L + t_3 - t_1}$$

In this equation t_1 is the initial temperature in deg. F. of the feed water; t_2 is the final feed water temperature; t_3 is the temperature in deg. F of the dry saturated steam at boiler pressure and L is the latent heat of steam in B.t.u. at boiler pressure and temperature.

In Fig. 1 is shown a chart from which the saving under different operating conditions can be readily calculated. In the example shown by the dotted lines and arrows, the steam is superheated 125 deg. F. at 150 lb. gage, the final feed water temperature being 190 deg. F. and the initial feed water temperature being 60 deg. F. By following the dotted lines it will be seen that the saving is 11.5 per cent. This method is one which has been used by Schutte & Koerting Co.

Assuming that the operator has now been convinced of the value of feed water heating, the next step is to determine what feed water temperature would result from the use of a certain amount of exhaust steam which might be available for such a purpose.

For this calculation G. F. Gebhart gives the following formula for open heaters in his book on Steam Power Plant Engineering:

$$0.9s\,(H - t + 32) = t - t_o$$

$$\text{or } t = \frac{t_o + 0.9s(H + 32)}{1 + 0.9_s}$$

In this equation, H represents the heat content of the water entering the heater; t_o the temperature of the water entering the heater; t, the temperature of the water leaving the heater and s the ratio of exhaust steam to the feed water by weight.

If more steam passes through the heater than can be condensed then this equation gives t, the final temperature of the feed water, a fictitious value, for t can never be greater than the temperature of the exhaust steam.

For illustration purposes the following example is used: A power plant has 1200 i.hp. of engines using 20 lb. of steam per i.hp. Auxiliaries use 2400 lb. steam per hour. Pressure in heater is 0 lb. gage, temperature of hot well supply 110 deg. F.

Here H equals 1150 (from steam tables), t_o equals

110 and s equals 0.10. Therefore, by substitution in the equation, we have

$$0.9 \times 0.10\ (1150 - t + 32) = t - 110$$

or $t = 198$ deg. F.

In the case of closed feed water heaters, the method is not so simple, as the water does not come in contact

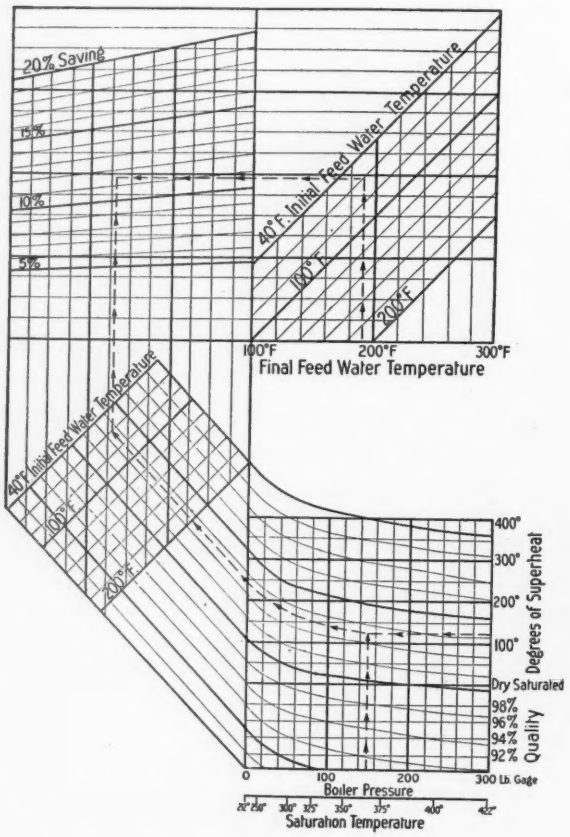


FIG. 1. FUEL SAVING IN PER CENT DUE TO FEED WATER HEATING

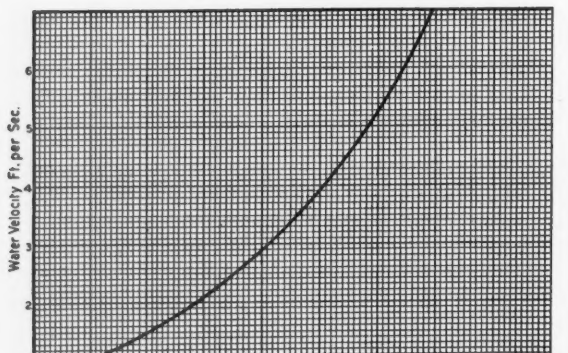


FIG. 2. HEAT TRANSFER RATE FOR A CLOSED TYPE FEED WATER HEATER

with the steam and the final temperature is dependent on a number of factors. It is usually assumed that the feed water temperature will be several degrees below the temperature of the exhaust steam and consequently the problem resolves itself into one of calculating the heater surface necessary for the particular conditions.

Harding & Willard in their book Power Plants and Refrigeration show this surface area to be

$$A = \frac{W\,(t_2 - t_1)}{U\left(t_s - \frac{t_1 + t_2}{2}\right)}$$

In this equation t_1 is the temperature of water entering the heater; t_s, temperature of steam entering heater; t_2, temperature of water leaving heater (t_2 is taken as 10 deg. less than t_s); A, sq. ft. of transmitting surface; d, mean difference in temperature between

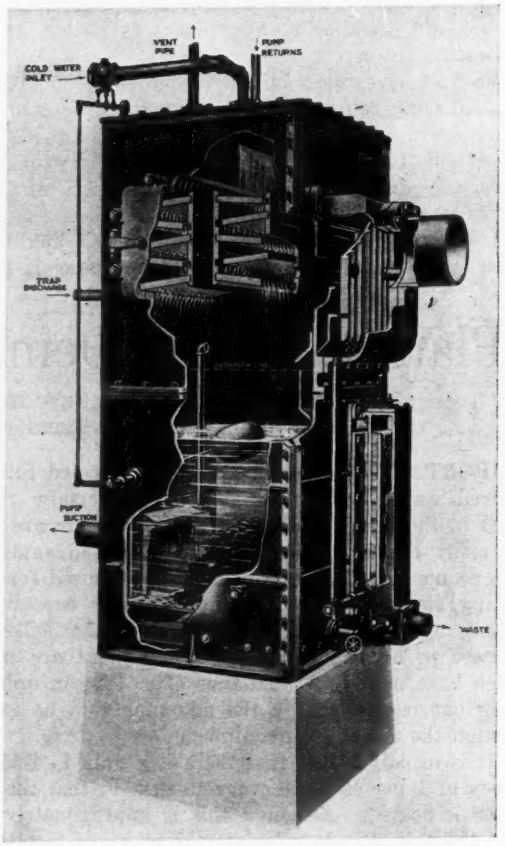


FIG. 3. OPEN HEATER OF THE TRAY TYPE

steam and feed water; W is the weight of feed water heated per hour in pounds and U is the B.t.u. transmitted to the feed water per square foot of surface per hour per degree difference in the average temperature of the steam and feed water.

Average values for this factor U are sometimes taken as follows: Multiple flow heaters with water velocity of 50 ft. per min. plain copper tubes 250 B.t.u., corrugated copper tubes 300 B.t.u. Single flow heaters with water velocity of 12.5 ft. per min.; plain brass tubes, 175 B.t.u. Coil pipe heater with water velocity of 150 ft. per min.; plain copper tubes 300 B.t.u. and for steam heated iron tubes, 120 B.t.u.

From a standpoint of economical operation the design of the heater is of considerable importance. In the open heater the pan or tray surface must be large enough to secure the desired heating effect. It has

been the practice in some instances to use more than the required pan surface in order to secure a more complete precipitation of the scale-forming substances.

Since the closed heater is practically the same in principle as a surface condenser, the laws of heat transmission are practically the same. Increasing the velocity of the water passing through the heater increases the

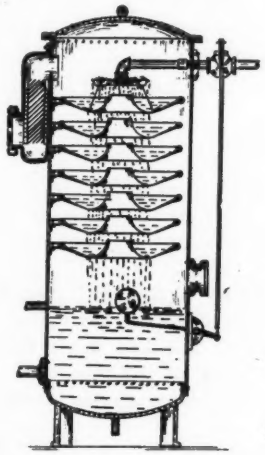


FIG. 4. ROUND PANS ARE USED IN THIS VERTICAL TYPE OPEN HEATER

rate of heat transmission, although it is necessary to have longer tubes in order to allow sufficient time for the water to be raised to the maximum temperature.

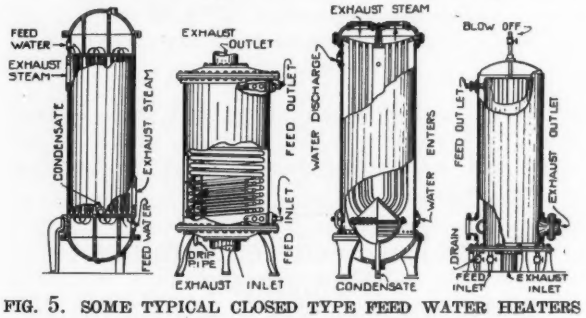


FIG. 5. SOME TYPICAL CLOSED TYPE FEED WATER HEATERS

Other things being equal, a heater containing a large number of small tubes of small diameter is more efficient than one containing a small number of large tubes.

In Fig. 2 is shown a curve which gives the rate of heat transfer for a closed heater of the multiple flow type. The tubes are 5/8 in. diameter of drawn brass. Such a curve as this gives the value of factor U used in the previous equation for calculating the area of the tube surface.

In making a selection of the type of feed water heater to be used, all of the operating conditions must be considered. After these points are considered it is well to make a thorough analysis of the various operating combinations which might be used. It is then possible to work out the temperature of the feed water, power consumed by auxiliaries, efficiency, first cost, fuel cost per year, and cost of operation per year, for the purpose of comparison. A few of the arguments, however, which have been used in discussing open and closed type heaters are as follows:

Open Heater	Closed Heater
Efficiency	
With sufficient exhaust steam for heating, the feed water may reach the same temperature as the steam. Scale and oil do not affect the heat transmission.	Maximum temperature of the feed water will always be 2 deg. or more lower than the temperature of the steam. Scale and oil deposit on the tubes and the heat transmission is lowered.
Pressures	
It is not ordinarily subjected to much more than atmospheric pressure.	Water pressure is slightly greater than that in the boiler when placed on the pressure side of the pump as is customary.
Safety	
Sticking of the back pressure valve may cause it to "blow up" if provision is not made for such an emergency.	It will safely withstand any pressure likely to occur.
Purification	
Since the exhaust steam and feed water mingle, provision must be made for removing the oil from the steam. Scale and other impurities precipitated in the heater are readily removed.	Oil does not come in contact with the feed water. Scale is removed with difficulty.
Location	
Must always be placed above the pump section and on the suction side.	May be placed anywhere on the pressure side of the pump.
Pumps	
With supply under suction two pumps are necessary and one must handle hot water.	One cold-water pump is necessary.
Adaptability	
Particularly adaptable for heating systems where it is desired to pipe the "returns" direct to heater.	All vacuum or primary heaters are necessarily of this type.

Difference between the total heat furnished by the boiler and the heat returned in the feed water is the net heat put into the steam by the boiler. Evidently the system which shows the least net heat required to produce one horsepower will be the most economical as far as coal consumption is concerned, although not necessarily the cheapest when both operating and fixed charges are considered.

Open and closed heaters are built in many styles according to different ideas on the subject and also to meet certain operating conditions and space limitations. Either kind may be had in either the horizontal or the vertical type.

All heaters in which the exhaust steam mingles directly with feed water belong in the open class. In this case the heating of the water is effected by pass-

ing the feed water down over a series of trays or pans. In Fig. 3 is shown a heater of this general type which make use of inclined trays. Another type shown in Fig. 4 makes use of round pans. The water flows over the edge of the pan and follows the under side of pan to the point where it drips off.

Steam enters through the side of the heater and comes in contact with the water film or spray, gives up its latent heat and condenses. Some of the scale-forming elements are deposited on the surface of the trays and the suspended matter is eliminated by a coke filter in the bottom of the chamber. Floating impurities are usually decanted by a skimmer, overflow weir, or blow-off.

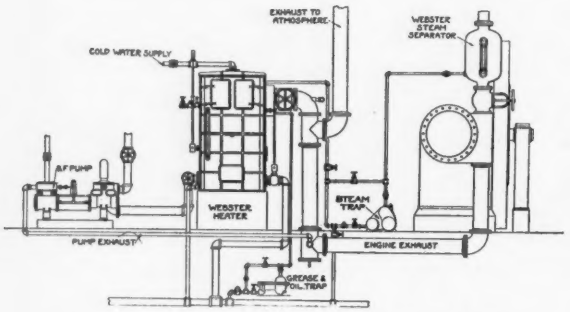


FIG. 6. LAYOUT OF OPEN FEED WATER PIPING

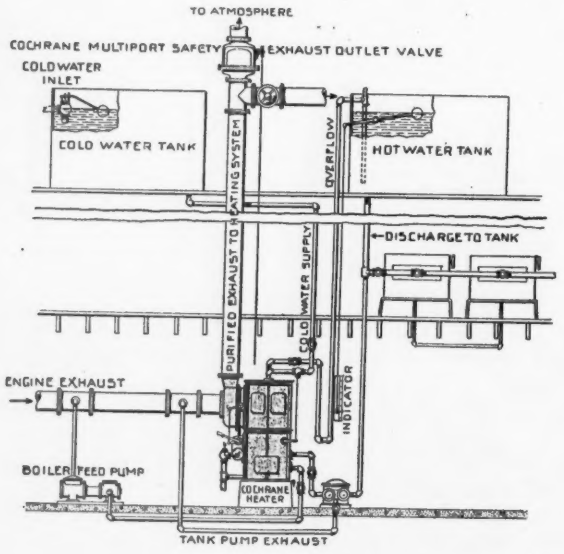


FIG. 7. OPEN HEATER LAYOUT WHERE EXHAUST STEAM AND HOT WATER ARE USED FOR INDUSTRIAL PURPOSES

There are variations of this general scheme among the different manufacturers but essentially the principles are the same.

In general a closed heater consists of a shell in which are placed a number of straight or curved tubes, usually seamless brass or copper. If the exhaust steam surrounds the tubes, the feed water passing through the tubes, the heater is of the water tube type. If the reverse is true, it is known as a steam tube heater.

Method of Installation

There are many arrangements possible for feed water heaters and the piping depending on the types of heaters used and the combinations involved through the use of vacuum and atmospheric heaters and the use of exhaust steam for heating of buildings.

In the case of the open heater the heater should be placed 4 ft. or more higher than the pump so that the hot water will flow into the pump suction by gravity. In Fig. 7 is shown a layout where exhaust steam is also used for heating and hot water is supplied for industrial purposes.

Arrangement of closed heater piping depends on whether all of the exhaust steam is to be passed through the heater or only a part of it. Frequently a secondary heater is also used which takes its supply from the exhaust of the auxiliaries. Such an arrangement is shown in Fig. 8. In this case cold feed water is pumped first to the primary heater and then to the secondary heater, whereupon it flows to the boiler. Besides raising the temperature of the feed water the primary heater also assists the work of the condenser. The secondary heater receives its steam supply from the auxiliaries.

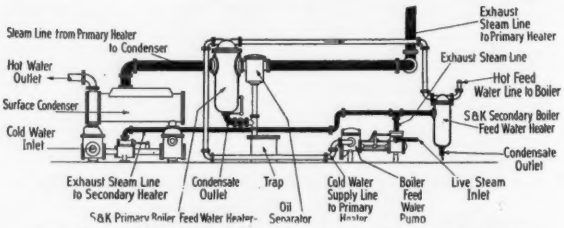

Steam Line from Primary Heater to Condenser
Hot Water Outlet
Surface Condenser
Cold Water Inlet
Exhaust Steam Line to Secondary Heater
Condensate Outlet
S&K Primary Boiler Feed Water Heater
Trap
Oil Separator
Cold Water Supply Line to Primary Heater
Boiler Feed Water Pump
Live Steam Inlet
Condensate Outlet
S&K Secondary Boiler Feed Water Heater
Hot Feed Water Line to Boiler
Exhaust Steam Line
Exhaust Steam Line to Primary Heater

FIG. 8. CLOSED HEATER PRIMARY AND SECONDARY INSTALLATION

Where a considerable quantity of such steam is available a back pressure as high as 15 lb. may be carried and a feed water temperature of about 245 deg. F. or over secured.

Control of Feed Temperature to Economizer

As economizer tubes begin to sweat when the initial water temperature is reduced to 120 deg. F. it is important that this temperature be carefully checked. It is therefore advisable to use recording thermometers on the line supplying water to the economizer so that a check on the operating conditions may be had.

From a standpoint of efficiency it is advisable to keep the temperature of the water as low as possible and yet not encounter the danger of condensing the vapor in the flue gases. Water temperatures of around 140 to 150 deg. F. are usually maintained.

When moisture accumulates on the exterior of tubes of economizers it combines with the sulphurous flue gases to form a weak solution of sulphuric acid. Corrosion is very rapid under such conditions.

Temperature control to the boiler is also important and a recording thermometer on the feed water is advisable. The higher the temperature can be maintained the more efficient the operating conditions. This is largely a matter of heat balance and means the most efficient use of exhaust steam without any waste to the atmosphere.

Effect of Boiler Feeding on Operation

EFFECT OF VARYING WATER LEVEL; IRREGULAR AND REGULAR METHODS OF FEEDING

BOILER FEEDING is a factor in the operation of steam power plants which has always been of considerable importance, although it must be admitted not as much attention has been given it as should have been the case. The safeguards thrown about the proper limits of water level fluctuations in a boiler do not begin to compare in cost, workmanship, accuracy or safety with those which govern the speed of a turbine. Operators have possibly inherited from the days gone by when "high water" or "low water" was less significant than now, a sort of easy familiarity with errors in water level regulation. The modern tendency, however, is toward much greater safety and refinement in the highly important function of boiler plant operation.

Water level in a boiler influences a number of things, such as priming, degree of superheat, ability to operate

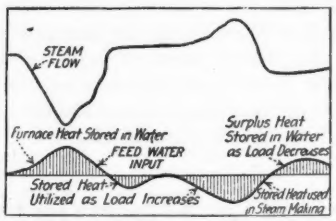

STEAM FLOW
Furnace Heat Stored in Water
FEED WATER INPUT
Surplus Heat Stored in Water as Load Decreases
Stored Heat Utilized as Load Increases
Stored Heat used in Steam Making

FIG. 1. RELATION BETWEEN STEAM OUTPUT AND FEED WATER INPUT WHEN REGULATOR IS ADJUSTED FOR STORING HEAT

at high ratings, etc. While the factors are all of importance, there is one which probably comes before any of those enumerated and that is the matter of safety—safety to life and safety to property.

If the water level falls too low, that is, below the point of highest heating surface, the boiler will be in danger of exploding; if, on the other hand, the level is carried too high, water will be carried over into the steam lines resulting, perhaps, in wrecking the engine or turbine connected to those lines.

It therefore becomes evident that in order to secure maximum safety in boiler operation, some form of automatic feed water regulator must be provided, especially in the case of large units operated at high ratings and under fluctuating load conditions. As a result there have been developed a number of automatic feed water regulators which relieve the water tender or fireman of the task of constantly keeping the water in the boiler at a safe level by hand regulation.

EFFECT OF VARYING WATER LEVEL

ASSUMING that the question of safety can be satisfied in boiler feed regulation, it will be of interest to consider the effect of water level upon other factors in boiler operation. It is a fact that the water level in the gage glass indicates almost every change in operating conditions, such as pressure changes, temperature changes, changes in the condition of the fuel bed, etc. Instantaneous changes in operating conditions are shown in the gage glass, consequently water level is a function of instantaneous changes in operating conditions. For this reason a steady water level with variable loads is wrong, and so is a variable level with a steady load. If the load is variable the water level should be variable; if the load is steady the water level should be steady.

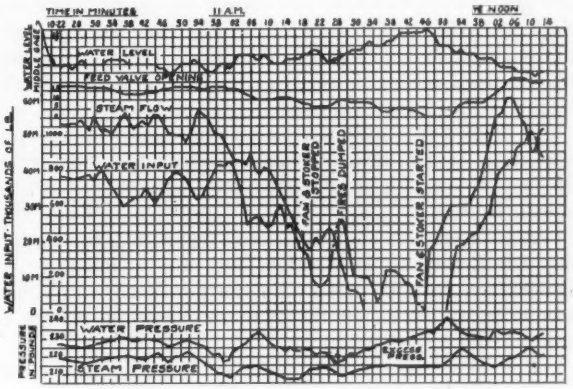


FIG. 2. TEST MADE BY THE ELMIRA WATER, LIGHT & RAILWAY CO. UPON A FEED WATER REGULATOR

At the present time our high boiler ratings, high furnace temperatures, and small water storage space call for a sensitive water level adjustment; every change in load should be met with a change in feed water input. That this is so will be evident from the following considerations: Suppose the temperature of the feed water is 180 deg., practically 200 deg. colder than boiler temperature. To make a pound of steam it is first neces-

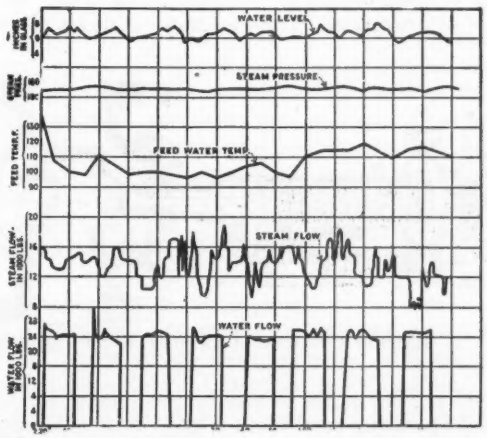


FIG. 3. SHOWING EFFECT OF IRREGULAR BOILER FEEDING

sary to heat the water 200 deg., thus adding 200 heat units, and then to evaporate it by adding 845 units more. That is, 20 per cent of the furnace heat must be utilized to heat the incoming feed water up to steam temperature.

If the boiler has practically no storage space, that is, if it would go dry were the feed cut off for only a short time, then it is necessary that the slightest change in load be accompanied by a corresponding change in

the flow of feed water. But an actual boiler holds a considerable volume of water, and when a demand for an additional supply of steam occurs, it is not necessary to increase the supply of feed immediately. Part of the water already in the boiler and at boiler temperature can be evaporated into steam, and this process may continue until the water has dropped to the lowest permissible level. Conversely, when the demand for steam falls off, it is not necessary that the amount of feed water be decreased simultaneously. On the other hand, the amount of water in the boiler can be increased so that the heat which would otherwise be lost is saved, and utilized by heating additional feed water. In other words, the furnace must be given time to adjust itself to the reduced load conditions.

In Fig. 1 is shown a graphic illustration of how an automatic regulator can scientifically adjust the rate of feed to varying load conditions. Another chart is shown in Fig. 2.

All foregoing considerations regarding the necessity for a varying feed water level, apply primarily to boilers operating under fluctuating loads. Where steady loads are encountered, there should be no variation in the water level.

For most satisfactory operation under steady load conditions, the feed water should be admitted to the boiler continuously at a steady rate, exactly coincident with the load. If water is admitted intermittently in slugs, it is apparent that it will be impossible to maintain the evaporation steady or to maintain a steady steam pressure. Each time the cold water is injected, the temperature of all the water in the boiler will fall slightly and evaporation will slow up, even though furnace conditions are held constant. In Fig. 3 is shown a chart made during a test by the flow meter department of the General Electric Co. which illustrates this condition. Each time water was injected into the boiler, the steam flow decreased; each time the feed was shut off the steam flow increased.

Priming

Priming was mentioned in the foregoing in connection with the subject of boiler feeding. This is often a serious source of trouble in boiler operation and may be due to a number of different things, among which, in addition to that of high water level already mentioned may be enumerated improper boiler design, high overloads and high concentration of impurities in boiler water.

Boiler design itself will influence priming insofar as liberating surface is concerned. The boiler should not have too small a disengaging surface and the construction should not tend to produce geyser action. This is often the case in vertical boilers with the water level below the top of the tubes. There should be ample surface from which the steam may rise.

Principles Governing Automatic Regulation

Feed Water Valve Control, Pump Governors, Value of High and Low Level Alarms

AUTOMATIC FEED water regulation contributes much to the economical production of steam because it controls the proper supply of water to each boiler in proportion to the amount of steam generated

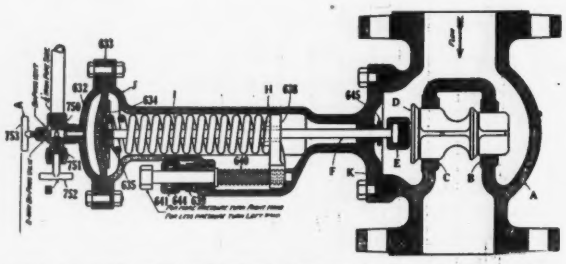


FIG. 1. SECTION THROUGH A TYPICAL PUMP GOVERNOR

without relying on the human personal equation. Under normal operating conditions, a good feed water regulator is able to maintain a level within from ¼ to 1 in. of the desired mark.

As discussed in other pages of this issue, it is not good practice to maintain a constant water level under varying conditions of load and some regulators are designed to lower the water level at heavy loads and raise it at light loads, the variation in height being adjusted according to local conditions. Other regulators are designed to maintain a constant level at all times; this type being suitable for use with installations operating under practically constant load conditions.

Feed Water Valve Control

Principles upon which modern feed water regulators operate may be divided into two general classes, i. e., those depending upon the use of floats or weights for their action, and those operating upon a thermostatic basis. The thermostatic regulators generally make use of the fact that a thermostatic element connected to both the water and steam sides of the boiler will respond to changes in the level of the water in the boiler. In some cases, the movement due to expansion or contraction of the elements itself is communicated directly to a valve in the feed line; in others it operates a pilot valve which in turn controls the valve in the feed line. There are also those in which steam or water pressure, in a generator, so called, is used to control the action of a pilot valve.

Regulators governed by the water level in the steam drum are of the continuous feed type in which the water flows at all times and the rate of flow is regulated in accordance with the water level in the drum; or they are of the intermittent feed type and the water is fed or not fed as the level falls below or exceeds a predetermined point in the steam drum.

Since in most cases the feed water regulator controls either directly or indirectly the degree of opening of the valve in the feed line, it is obvious that the rate of flow will vary in accordance with the area of the valve opening, provided the pressure in the feed line is maintained constant. Now, this last requirement is by no means assured, for should the boiler at any time take

but little water, the feed pump would tend to build up an excessive pressure in the water main. This excessive pressure would manifest itself in excessive flow as soon as the feed valve opened again. In other words, there would be a continual variation of pressure in the feed water line depending upon the rate of opening and closing of the feed valve.

To overcome this objectionable feature, the regulator is often connected so as to control the action of the pump by means of a back pressure regulator which is placed in the steam pipe of the pump and thus regulates the pressure in the water main from the pump to the boiler. With this arrangement, the pump cannot cause an excessive pressure to build up due to a slowing up of injection.

Pump Governors

This use of the pump governor in connection with a boiler feed water regulator constitutes a most satisfactory arrangement. Tests have demonstrated that variations between the steam pressure and water pressure are costly. If the feed line pressure is not kept at an exact fixed constant above the steam pressure and at the same time vary in direct proportion as the steam pressure varies, then the increase or decrease in pressure between the steam pressure and water pressure entering boilers gives an unbalanced feeding condition regardless of whether hand feed or automatic regulation is used.

Modern types of pump governors are designed to keep the feed line pressure always at a fixed constant above the steam pressure. This eliminates changes in the rate of feeding caused by variations in the feed line pressure.

In Fig. 1 is shown a sectional view of a typical pump governor for use in connection with boiler feeding. The governor consists of a double diaphragm chamber, as shown by the recessed portion of 632 and the flanged end of the spring case J. The back pressure for water pressure is piped to a two-way bypass at 750.

In actual operation the spring case H is filled with condensation up to part 645 and the steam pressure rests upon this water, thereby exerting pressure on the diaphragm. This tends to pull valve disc D off the seats, thereby admitting steam through the valves.

The spring I is placed as shown and rests upon a plate in contact with the diaphragm. This spring pressure, plus the steam pressure, keeps the valve disc off the seats when there is a demand for water. In order to make the governor shut off tight, the back pressure on the water side must build up to exceed the steam plus the spring pressure.

In operation and when more or less water is being used, the governor never shuts off, but floats with the demand and always maintains the desired excess water pressure over the steam pressure and with no variation between these pressures. The governor may be adjusted to maintain any desired pressure over the steam pressure by merely turning the adjusting screw 641.

In Fig. 2 is shown another type of pump governor. Although the principle of operation upon which the action of this governor is based is essentially the same as in the one previously described, the method of control is different in that a pilot valve is employed. Its operation is as follows:

Pump pressure acting on the diaphragm of the pilot valve is balanced by the tension of a spring. This tension may be varied by an adjusting nut. If pump pressure overcomes the spring tension, the pilot valve F is seated. Steam then seeps past the plug of the pilot valve (resistance plug), increasing the steam pressure on the main diaphragm, and decreasing main valve opening. If the pump pressure is overcome by the spring the pilot valve is lifted off its seat and the exhaust port is opened; pressure is reduced on the main diaphragm and the main valve opens up, admitting more steam to operate the pump. There will always be a slight exhaust from the pilot valve, showing that the valve is

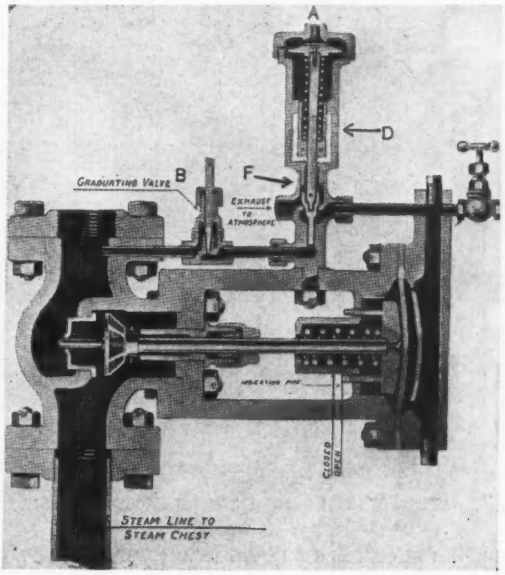


FIG. 2. PUMP GOVERNOR USING A PILOT VALVE

just off the seat and a steady pressure maintained on the main diaphragm, holding the valve open just enough to maintain the desired pressure.

Regulators of the foregoing type are used extensively with widely varying steam pressures. Positive displacement power pumps are regulated either by varying the speed of the prime mover, or by a bypass control, which opens the discharge from the pump to suction, allowing the water to circulate through the pump. A check valve prevents the water in the discharge line from flowing back into the pump.

These machines are usually belted to a constant speed source of power, or are motor driven; the speed of the driver can be varied only when it is a direct current or wound rotor motor, and even then the control apparatus is apt to be complicated.

Value of High and Low Level Alarms

High and low level water alarms are placed on boilers to give warnings to those in charge of a boiler if the water varies above or below the proper level. Of course, it may be argued that the automatic feed water regulator is supposed to maintain the water level between certain limits, and for this reason the high and low level alarms are superfluous. True enough, the automatic regulator is supposed to do this, and under ordinary conditions it does this in an entirely satisfactory

manner; yet the automatic feed water regulator may fail or the water supply to the boiler itself may fail. It is then that we need the high and low (particularly the low) alarms.

In many cases only the low level alarm is provided, since of the two conditions, excessively high or extremely low level, the latter is perhaps the most danger-

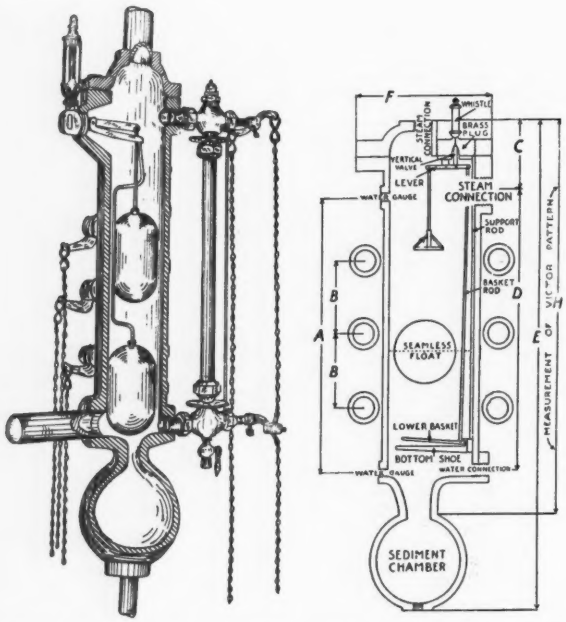


FIG. 3. SAFETY WATER COLUMN WITH HIGH AND LOW LEVEL ALARM

FIG. 4. HIGH AND LOW LEVEL ALARM WITH FREE FLOAT

ous, and is therefore the one to be most guarded against. High water level, on the other hand, is also to be guarded against for while it is not so dangerous to human life as low water level, it may, particularly in the case of large turbine installations, prove costly due to slugs of water stripping the turbine blades. For maximum safety, therefore, it is well to provide both the high and low level alarms.

While the value of the water level alarm cannot be doubted, the objection has sometimes been advanced that their use causes the fireman or water tender to grow careless in watching the gage glass. In other words, too much reliance is placed upon the action of the alarm, which it must be admitted, like any other mechanical device, is subject to failure. Although the logic in this argument is apparent, it does not carry sufficient weight to justify the non-use of water level alarms. In fact, any protective device might be considered from this point of view and it would be just as reasonable to disclaim the use of safety valves or over-speed protective devices on engines because of their possible failure to operate.

Water level alarms must not be used in ordinary routine operation to indicate when or when not to inject water into the boiler. Gage glasses and try cocks are provided for this purpose. The limits of water level indicated by the alarms are too extreme for normal operating purposes and should not be depended upon. Instead of its tendency to make employes careless, the alarm is used by well-run power plants as a means of helping to maintain discipline. No water tender is allowed to depend on the whistle or bell of the water level alarm to tell him that the water level is needing attention. He knows that the whistle is not supposed to blow except when the column is blown down between shifts, and that if it does blow, he will have to explain why.

Types of Water Level Alarms

Water level alarms are made in various types, although most of them depend upon the use of floats for their action. In some cases the action is based upon the melting of a fusible plug.

A typical safety water column equipped with both high and low level alarms is shown in Fig. 3. This is a device which gives an unmistakable signal when the water level in a boiler rises or falls beyond certain predetermined points. It consists of a semi-steel body casting containing the alarm mechanism. This is installed on the boiler in place of the plain column ordinarily

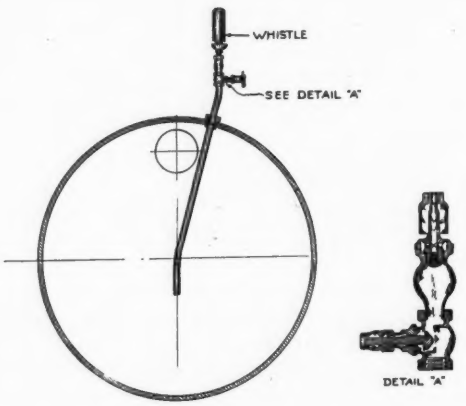


FIG. 5. LOW LEVEL ALARM USING FUSIBLE PLUG

furnished. The signal may be given by a whistle, by two whistles, by an electric attachment, or by combinations of these. In this alarm, the two floats, actuating the high water level and the low level signal, respectively, are attached to the valve levers by means of rods, as may be noted.

In another make of safety column, shown in Fig. 4, the float is free. As the water lowers, the float is brought in contact with the low alarm water basket and its weight operates the low water alarm. Should the boiler become too full of water, the float rises up against the upper basket, its buoyancy operating the high alarm.

Another type of alarm is shown in Fig. 5. This is a low water alarm only, and is shown in Fig. 3 as applied to a B. & W. boiler. It combines a fusible plug melting by steam temperature and a whistle alarm which is sounded when the low water line is reached. Under a satisfactory water level the condenser is occupied by water, thus protecting the fusible plug filler. When low water is reached the water is replaced by steam which melts the fusible plug and sounds the whistle alarm. A new fusible plug filler inserted in the whistle portion puts the device in service again.

Delivery of Feed Water to Boiler

IN THE design of a boiler installation care must be taken to locate the feed pipe properly. The method of discharging feed water into boilers has two important bearings upon the economy in the boiler room;

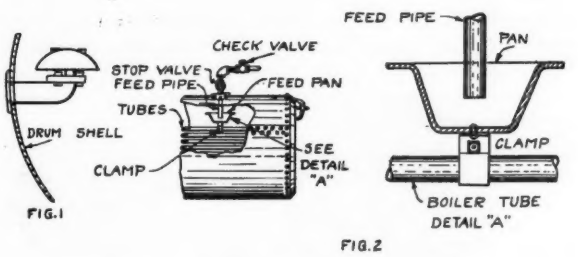


FIG. 1. UMBRELLA TYPE OF DEFLECTOR
FIG. 2. FEED PIPE EQUIPPED WITH SPRAY PAN

these are to help increase circulation and to deposit the sediment where it will be least harmful.

Before the water is discharged into the drum it is well to lead the pipe around through the water space a turn or two in order to heat the water so that when it comes in contact with the heating surfaces it will cause no serious contracting strains in the boiler metal. When finally discharged from the pipe, it should be in that part of the boiler where the least evaporation takes place and in the direction which is the natural circulation for the water in the boiler at that point. By this simple arrangement the circulation is increased and the deposits are washed to that part of the boiler just over the

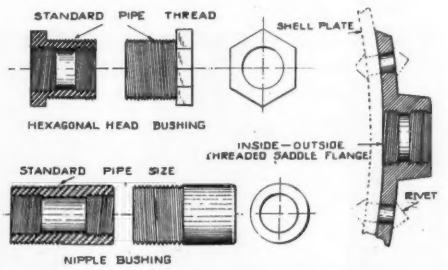


FIG. 3. METHOD OF CONNECTING FEED LINE INTO BOILER

blowoff where they can do the least damage, and are easiest removed.

Location of Delivery Pipe

According to the A. S. M. E. boiler code, the feed pipe of a horizontal return tubular boiler should enter the front head immediately above the tubes and should extend back about 3/5 of the length of the boiler. The water should be discharged above the central rows of tubes. By flowing through a length of pipe inside of the boiler, the feed water gradually becomes heated and by the time it is discharged it is of a comparatively high temperature.

In some cases, particularly in marine boilers of the water-tube type, the internal feed water lines are fitted with "umbrella" deflectors of the form shown in Fig. 1, for the purpose of deflecting the feed water downward to as many of the downcourse nipples as possible.

Another method of discharging the feed water is shown in Fig. 2. With this arrangement, the water is discharged in the form of a spray by allowing it to spill over the edge of a pan. This spray pan may be a long trough with saw-tooth edges. Because of the tendency of the sprayed feed water to be carried away with the outgoing steam current, this method is objectionable; however, by locating the spray pan as far from the steam connection as possible such entrainment is to a certain extent avoided.

On account of the comparative coolness of the incoming feed water, the discharge should not be located near a riveted joint or furnace sheet. Should the discharge be so located, the cool feed water would chill and contract the plate or seam upon which it is permitted to discharge. The local contraction thus produced would cause severe straining of the metal.

Where the feed pipe enters the head of the boiler the attachment should be made with a bushing or a flange, as shown in Fig. 3.

In any case, the underlying principle to be kept in mind when installing the feed line to a boiler is that the change in temperature of the feed water should be as

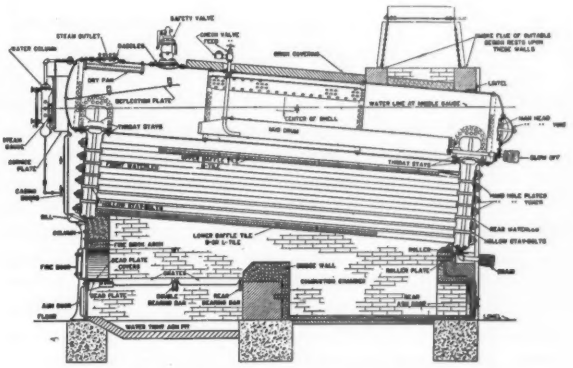


FIG. 4. SECTION THROUGH STANDARD BOILER SHOWING LOCATION OF INTERNAL FEED LINE

gradual as possible. The feed water should be discharged in that region of the water space where the ebullition is least violent.

In Fig. 4 is shown a longitudinal section of a standard water-tube boiler in which the method of locating the feed line may be noted.

Feed water deposits sediment and scale-forming material in the pipe, particularly in plants where the water is hard and no water softening equipment is installed. The discharge capacity of the line is thus diminished. For this reason it is advisable that the feed piping be jointed and located so that it may be easily cleaned.

Another thing that should be considered when installing a feed line to a boiler is the provision of suitable fittings. A feed pipe should be provided with a check valve near the boiler and a valve or cock between the check valve and the boiler, in fact, this is required by the A. S. M. E. boiler code. When two or more boilers are fed from a common source, there shall also be a globe valve on the branch to each boiler between the check valve and the source of supply. Whenever globe valves are used in this manner, the inlet should be under the disc of the valve.

Several Types of Feed Water Regulators Available

THERMOSTAT, PRESSURE GENERATOR, OR FLOAT ARE METHODS USED TO CONTROL FEED VALVE IN VARIOUS TYPES OF REGULATORS

CONSIDERING the comparatively recent origin of automatic control for boiler feeding, the study made in the development of this apparatus stands as one of the fine achievements of power plant engineers in working toward higher efficiencies in the boiler room. This apparatus is out of the experimental stage and has now settled down to certain definite types of equipment each of which has its merits depending on the size of the plant, operating conditions and the particular results which are desired.

As the control of the boiler feed is dependent both on the opening of the feed valve and the variation of the

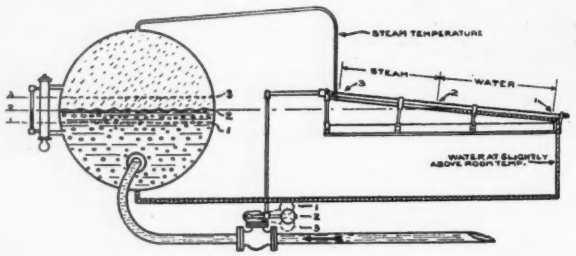


FIG. 1. VARIATION IN AMOUNT OF WATER AND STEAM IN AN INCLINED TUBE CAUSES EXPANSION WHICH OPERATES FEED VALVE

feed pressure with the boiler pressure, apparatus has been designed to control one or both of these operations automatically. As a further refinement, the control apparatus has also, in many cases, been designed to control the boiler feed with reference to the particular operating conditions at the time. This variation of the water supply with increasing and decreasing boiler load is covered in another article in this issue which goes into the theory of such control.

Feed water regulators depend on the use of either a thermostat, float, or pressure generator to receive the required force necessary to operate the feed valve.

REGULATOR UTILIZING THERMOSTAT

IN FIG. 1 is shown a schematic layout for a regulator actuated by the expansion and contraction of a heavy metallic tube mounted on a base and connected by a lever and a control valve in the feed line. This expansion tube is set in an inclined position opposite the water level in the boiler and is connected to the steam and water spaces as shown. As a result the water level in the inclined tube is the same as that in the boiler.

In the upper end of the tube, the steam space is filled with steam at boiler temperature while the part below the water line of the boiler is filled with water. The temperature of this water is slightly above room temperature due to cooling by radiation.

At normal load with water level at position 2, half of the expansion tube is filled with steam and half with water and the tube expands and assumes a length that opens the control valve to position 2. As the load gradually increases the water level falls and the tube is filled with steam. This expands the tube and causes the feed valve to open to position 1.

With a sudden increase in load there is a drop in boiler pressure which releases heat stored in the water. This heat in the form of steam bubbles causes the water level to rise, hence the regulator decreases the valve

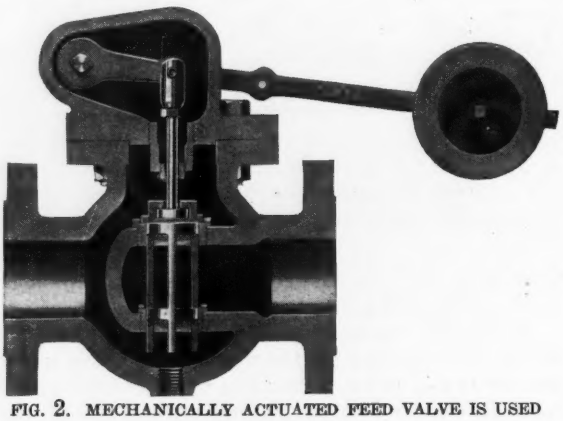


FIG. 2. MECHANICALLY ACTUATED FEED VALVE IS USED WITH REGULATOR

opening. It can, therefore, be seen that the boiler feed rate is reduced in cases of a sudden peak load. If the load drops off suddenly there is a rise in pressure, boiling ceases, with a resulting fall in water level. More steam is admitted to the thermostat tube and the feed valve opening is increased.

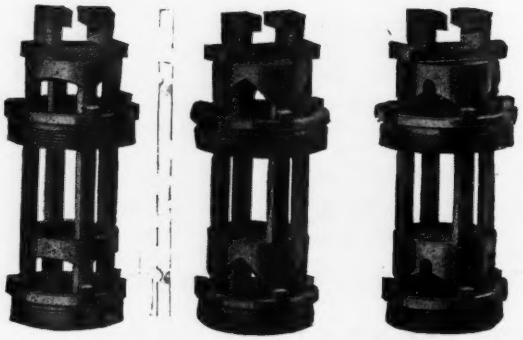


FIG. 3. VARIATION IN VALVE PORTS WHICH GIVE DIFFERENT RATES OF FLOW

As the opening of the feed water valve is the function of the regulator, the design of this valve is of importance. In Fig. 2 is shown the control valve. These valves are also furnished with three styles of port openings as shown in Fig. 3. The rectangular port opening, on the left of Fig. 3, produces a flow that is directly proportional to change in the load. When a peak load is subsiding the water storage increases more rapidly than with the other two types shown. With the V shaped port shown in the center view the flow is not proportional to changes in load. It produces greater water level variation at light loads than on heavy loads. The port shown on the right of Fig. 3 is known as a compound port valve. In this case the flow is propor-

tional to the load on light loads as well as on heavy loads and its use is recommended on boilers that frequently carry lights loads, but must also be ready to carry heavy loads.

Use of Steam Generator to Actuate Feed Valve

Actuation of the feed valve of the regulator shown in Fig. 4 is obtained by using a generator. This generator consists essentially of an inclined tube which is placed at the point of high and low water levels. Surrounding this tube is a radiator type tube which is connected to the control valve, shown in Fig. 5, by means of copper tubing. All of this generator space is filled with water.

Assuming that the water level in the boiler is at the top of the generator, with the feed valve closed, the water level will begin to drop as the boiler takes its load. As soon as the water level has dropped, steam enters the inner tube and heat is taken up from this

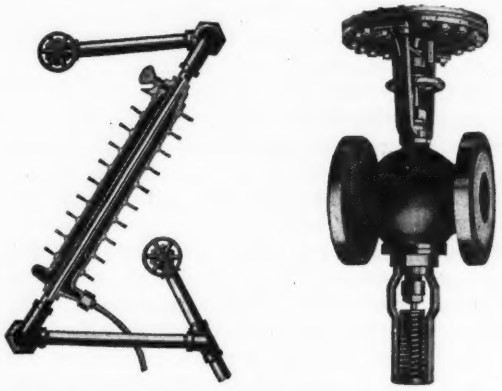


FIG. 4. PRESSURE IS CREATED IN GENERATOR OF REGULATOR WHICH OPERATES FEED VALVE

FIG. 5. REGULATOR EMPLOYS DIAPHRAGM OPERATED FEED VALVE

steam by the water in the generator. Enough heat is so taken up to create a pressure in the generator and this pressure is transmitted by the water through the copper tubing to the diaphragm on the feed valve. This valve therefore opens a proportionate distance.

It will be noted that the water in the generator is forced out as the diaphragm gives way. By using properly proportioned radiating surfaces and a certain size inner tube it has been found possible to keep the water height in the generator about the same height as the boiler level in the inner tube. This radiating surface also takes care of any surges in the boiler by making the absorption of heat by the generator more uniform and slightly sluggish in action.

Where the load increases suddenly, the rising water level, due to increased boiling through lowered pressure, causes the valve opening to be reduced as the steam supply to the generator is reduced. The reverse is true for sudden decreases in load.

As can be seen from Fig. 5, the feed valve has a special type of valve disc. This disc gives a restricted flow for small valve openings. It is also possible to use this regulator for the control of the feed pump where just one pump and one boiler make up the installation.

Regulator Using Gravity Weight

Instead of using a float to secure the movement necessary to open a pilot valve, one regulator uses a gravity weight. From Fig. 6 it can be seen that this weight is counterbalanced and as the water rises around

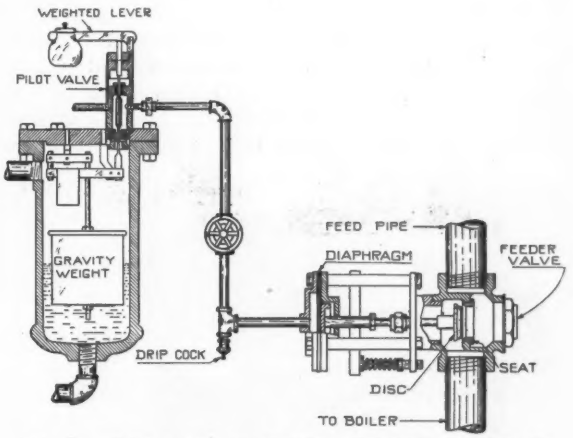


FIG. 6. PILOT VALVE IS OPENED BY DISPLACEMENT OF GRAVITY WEIGHT

it there is a force exerted by the counter-weight due to the gravity weight displacing a certain volume of water. Consequently the pilot valve is opened admitting steam to the diaphragm which closes the feed valve. When the gravity weight falls the operation is reversed.

Float Controlled Regulator

Another type of regulator, of which several makes are available, has the pilot valve opened by a float. In

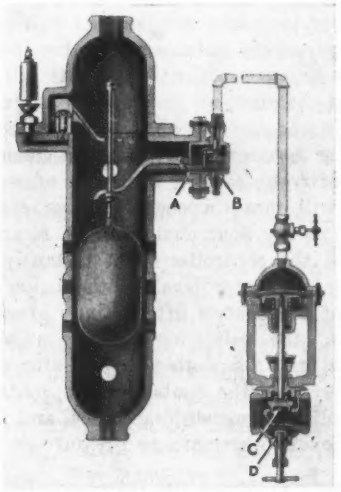


FIG. 7. PILOT VALVE IS OPERATED BY FLOAT

Fig. 7, which is illustrative of this type, the feed valve C is shown in the open position. As the float rises the knocker on the float rod lifts the lever and opens the operating valve A, admitting boiler pressure to the operating chamber by allowing the exhaust valve B to close. The pressure communicated through the connecting pipe to the top of the diaphragm overcomes the spring and closes valve C. As the water falls, the reverse operation takes place.

There is also a valve, D, which is opened to admit water at a slightly lower rate than that at which the boiler evaporates. In this way valve C opens at infrequent intervals, admitting enough water to make up the difference between that evaporated and the amount passing through the continuous feed valve.

As regulators of the float type tend to close the feed valve with rising water level, the feed is reduced under sudden load conditions. As previously pointed out, the water level in a boiler tends to rise under sudden increasing load and falls off when the load drops off rapidly. Consequently these regulators also give a certain compensating effect which is desired for sudden load variations.

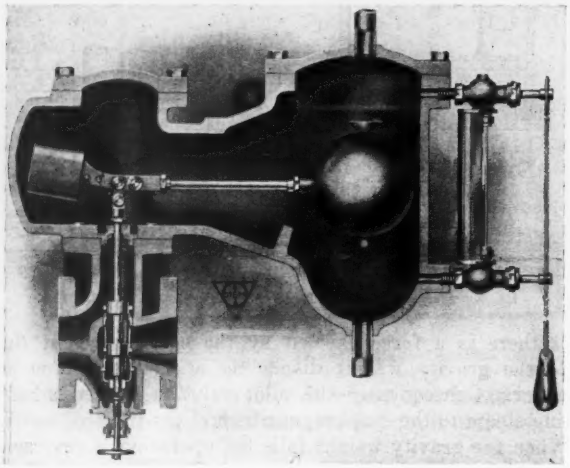


FIG. 8. FEED VALVE IS OPERATED BY DIRECT ACTION OF FLOAT

In another type of controller, the valve is of V port construction and is actuated by the lever attached to a float. The controller is set with the center line of the float-chamber at the normal water level line of the boiler and the top and bottom of the controller float chamber connected to the boiler steam and water spaces respectively, so that a change of water level in the boiler will mean a corresponding change in the water level in the float chamber. It is apparent that the valve of the controller must instantly respond to every change of water level in the boiler and as the movement of the float is fifteen times greater than the movement of the valve itself sticky valve movement is eliminated and a smooth flow of water assured. All actuating parts of the controller are contained within the casing eliminating stuffing boxes, and it is possible to control flow of water at any pressure or temperature.

Regulators Must Be Properly Installed

Like any other piece of apparatus, feed water regulators must be properly installed and maintained if the operating results are to be satisfactory. To install such equipment in a haphazard manner and then not inspect it periodically is to breed trouble. With just a little attention it is probable that all of the feed water regulators on the market will give good service, within the limits of their design.

Regulators should be mechanically dependable and positive in opening and closing the feed valve, and the actuating force should be great in proportion to the internal resistance of the regulator so that the opening of the regulating valve will be smooth and continuous and not a "step by step" motion. The adjusting of the regulator should be permanent and it should have the same characteristic action each and every day.

In making an installation, the first point to be considered is the average water level to be carried. Convention has fixed this usually as the center of the drum, but this level is being found too high, particularly in turbine plants. Oftentimes the position of the water in the glass is no measure of the height of the water in some other drum and slugs of water go over into the turbine.

High Water Level Not Advisable

Gage glasses do not always indicate correctly as that side of the drum receiving the cold water will have the lower level, because the water on that side is heavier per cubic inch and because it has no bubbles of steam in it. These two levels in a boiler are sometimes known as the weight level and volume level. It is probable, then, that the average water level can be dropped 2 or 3 in. where a feed regulator is used.

Several years ago a Brooklyn station had considerable trouble with water going over into the turbines. After installing a regulator and carrying high water not above middle gage, all water trouble was eliminated. They also eliminated burned tubes, although the average water level was low.

Another point is the excess pressure in the feed line above boiler pressure. Some authorities say this should be around 10 to 15 lb. With this pressure, a 2½-in. regulator valve will pass water for 2500 boiler hp.

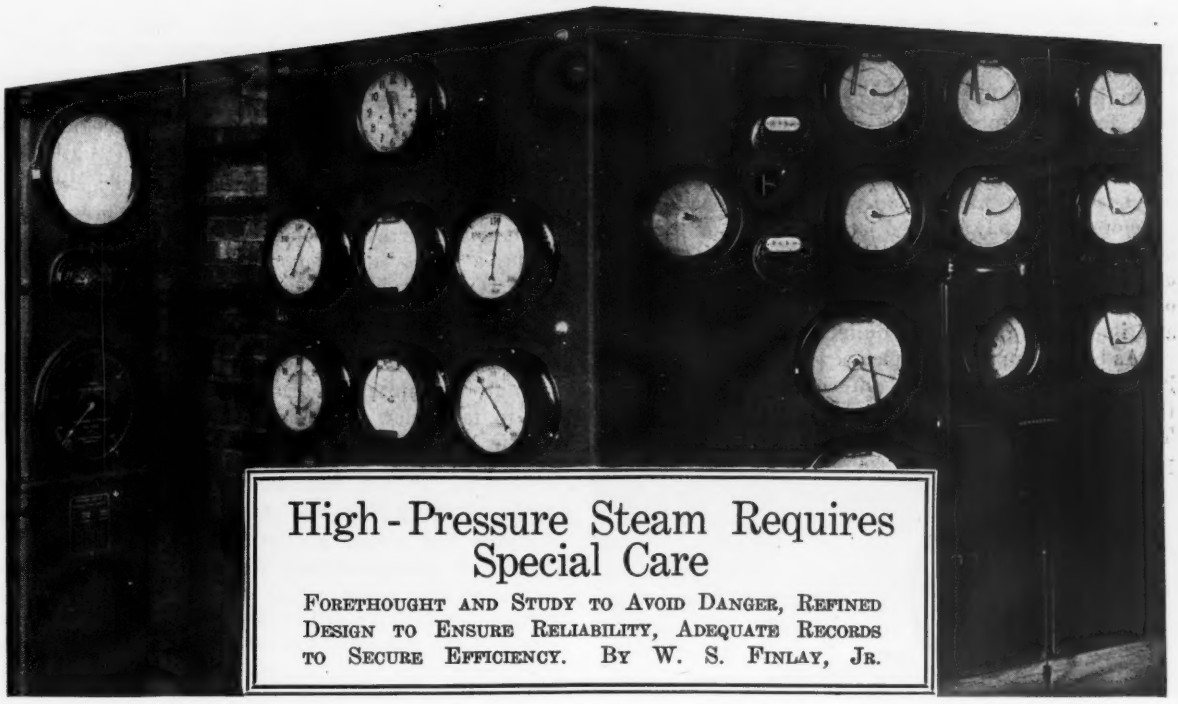
Some plants want less pressure and others want as high as 60 lb. In one instance the latter pressure was used in a plant and it resulted in carrying an extra pump in service, cutting the valve seats to pieces in six months and causing indifferent feeding. When the pump pressure was reduced, one pump was eliminated and the feeding smoothed out. Most operators do not realize that too large a valve, or too high an excess pressure will give feeding intermittent in character irrespective of the regulator employed.

Use of Two Regulators

Feed water regulators should be attached to the same part of the boiler as the gage glass as one checks the other. On large boilers two regulators should be used to compensate for differenees in operating conditions and to distribute the cold water.

There is a tendency to specify regulators on the amount of water they will pass with a given excess pressure. The essence of good regulating is a smooth continuous movement of the valve with properly designed ports for the excess pressure carried. There is also a tendency among operators to insist on having an indicator on the valve which will show the opening. In this way it is possible to check up with the water glass and pump pressure.

One point which always arises is the question of a bypass for the regulator. If the feed water regulator is inaccessible or difficult to cut out of service, a bypass is a necessity. Where the regulator valve can be easily opened manually, the bypass then becomes a matter of individual preference.



High-Pressure Steam Requires Special Care

FORETHOUGHT AND STUDY TO AVOID DANGER, REFINED DESIGN TO ENSURE RELIABILITY, ADEQUATE RECORDS TO SECURE EFFICIENCY. BY W. S. FINLAY, JR.

NORMALLY the engineering mind insists upon logical division of any problem under analysis into cleanly-cut component parts. Possibly usage is responsible for the customary separation into two or three parts of what is actually a single unit—the steam generator—attempting to consider separately the combustion and evaporation processes. Whether we are permitting ourselves to follow old-time and well-beaten paths of professional practice, or are influenced by the fact that the components of the whole are generally turned out by different manufacturers, nevertheless the writer firmly believes that in doing so we are continuing in what he considers a decidedly faulty method of attack and one which will unquestionably be and in fact now is being abandoned by advanced students in this particular field of practice.

Hitherto production economics have generally forced the engineer to select his water and steam container (commercially termed the boiler), largely from stock designs, adapting stock combustion thereto in the combination which seems to meet most nearly the needs of the particular installation. Recent developments, however, are forcing a complete change in practice, which the boiler manufacturer seems inclined to accept partially, and to which, for instance, pulverized fuel developments are giving excellent impetus.

This particular analysis, however, has been predicated upon a subdivision of the complete unit and concerns the water and steam container and distributing system.

To avoid over generalization it seems proper to set up markers which will serve to classify the analysis and to conduce to a simple presentation. For these markers there have been selected three general considerations affecting boiler design and operation: (1) efficiency, (2) reliability, and (3) safety, their development being presented in the following.

EFFICIENCY

FROM a dollar-and-cents point of view, it is most fortunate for the engineer that every boiler problem involving the combination of a number of different features permits of and actually calls for individual solution. Ideally, it would be fortunate for the user if the stock boiler, stock stoker, stock superheater, stock economizer and stock everything could be accommodated to every need; but that custom has been severely jolted by the call for steam supply involving pressures and superheats, ratings, and load factors heretofore scarcely contemplated. The result is new problems whose solution has necessitated radical changes in hitherto stereotyped boiler designs, forecasting what will probably be revolutionary changes in no distant future.

Demand for high efficiency—the securing of the last fraction of return on the invested dollar—has created quite a number of interesting problems, as for instance in (1) the materials to be used and design of the boiler (including tubes and drums); (2) elaborate precautions for the prevention of scale and accumulation of sediment; (3) the design and location of the superheater, to secure a steam temperature whose variations shall be within a given range or shall meet the demand of the paraticular installation; and (4) the use, to meet pressure conditions, of economizers with steel tubes, bringing with them the problems of cleaning and corrosion prevention. Each of these in itself presents an individual problem and in fact indicates a series of problems whose solutions time alone can effect.

As incidental to each problem there is presented the increased necessity of providing suitable measuring apparatus to check each possible loss and to assist the user, while reaching for high efficiency, to keep the element with which he is working under safe control. It would be improper and is illogical to set forth any preferred list as to type of indicating and measuring instru-

ments. The same rule applies to instrument application as to boiler design—each problem has its individual solution.

Indicating instruments, measuring rate of steam flow, find their place in nearly every plant to show boiler performance. Records of steam flow for individual units may or may not be necessary, largely depending upon whether or not the information can be more accurately secured at the boiler or at some other point in the system. Frequently with a number of small units the record covering a section or group of boilers is sufficient for the guidance of the operators, and individual records are quite unnecessary.

As bearing upon both efficiency and safety it is absolutely essential to have full information concerning the temperature of steam when superheated to any extent. The charts from recording apparatus utilized for the purpose have been and will continue to be valuable wit-

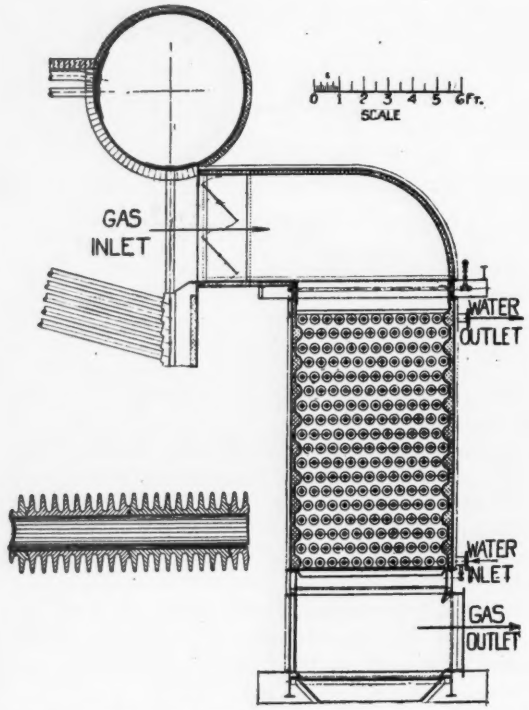


FIG. 1. MODERN STEEL-TUBE ECONOMIZER AND DETAIL OF CAST-IRON JACKETED TUBE

nesses in tracing back to the source such matters as turbine troubles caused by high temperatures, "slugs" of water that have been thrown over from the boilers, etc.

Indicating pressure gages can be supplemented to advantage by master recording gages, giving records which assist in tracing trouble and avoiding it by showing the trend of steam conditions, which is a matter just as important to observe as the reading of the moment.

To the writer's knowledge, no apparatus has been developed to record the character of superheated steam. As to what part, if any, dissociation and steam breakdown play and their relative importance as incidental to the superheating of steam, little of definite value is known or at least little has been made public. During the past few years such chemical breakdown has been used as selling talk for some superheaters, as has also the value of "mixing" and uniformity of application of the superheating process; but it would be interesting to know whether these considerations are recognized as of such importance that the instrument man is attempting to measure them and whether such apparatus will become necessary to boiler operation.

Omitting further discussion of methods for maintaining a check upon superheat of steam, too great emphasis cannot be placed upon proper provision for insuring that the supply will closely conform to the needs of the machine in which it is to be used. The effect on over-all efficiency of a steam turbine plant of failure to maintain a steam supply or allowing superheat to fall below that for which provision has been made in the turbine design is obvious.

Reliability

In present day power plant design and operation reliability has become a most important consideration. Securing it in high degree where it is most essential has necessitated some rather rapid engineering development, particularly in the case of "base load" plants, in which the demands incidental to high load factor operation give no breathing spells for the quick repairs, adjustments, and cleanings which would otherwise serve to lengthen the active service periods and reliability of boilers and other apparatus. Such conditions are, however, not necessarily unmixed evils. They have forced the designer and manufacturer to meet these conditions of service by introducing rather larger factors of trouble prevention than have hitherto been considered necessary. At the same time boiler walls, steam mains, etc., are actually standing longer in service because of being freed to a large extent from that bane of peak load plants, expansion and contraction strains which result from frequent shutdown and re-entry to service.

To meet the demand for reliability in service, what may seem excessive precautions have been taken to safeguard against every source of trouble that might result in even a momentary interruption of service. This has no reference to spare equipment. Beginning at the boiler end and running through the turbine, typical instances are as follows: (1) Special arrangement in the way of light and quickly-handled access doors for internal and external cleaning of tubes; (2) the development of baffles designed for long life and hard service; (3) accessibility for internal inspection and external cleaning of superheaters; (4) accessibility for maintenance and care of boiler and superheater joints; (5) strength, simplicity, accessibility in economizer design, placing it more on a parity with and tying it in closer to the boiler; and (6) greater consideration given to the mechanics of piping design.

This last has opened a door of peculiar and interesting opportunity, although hitherto it has been too frequently a field for experimentation by the artistic draftsman rather than the analytical engineer. Particularly in service at high temperatures, the mechanical effect of expansion and contraction strains is only too frequently overlooked. One instance occurs to the writer in which the design of the steam line to a large turbine had been most carefully planned for the avoidance of just such strains. After two or three shutdowns in

operation the trouble was traced directly to the strain imposed by this particular line in a manner absolutely unforeseen by the very able engineers who planned it. That the same shutdowns did not occur to duplicate installations in the same plant was because certain bracing, which was partially the cause of the trouble, had been, in the case of the other machines, torn loose through heat strain and the cause of the trouble thus automatically removed.

Steam line design has been found in which failure, in the operation of the drainage system of "pockets" has resulted in the carrying over of slugs of water and destruction of turbine blading.

Undoubtedly the cause of many failures that have occurred under conditions such as mentioned above has been our lack of familiarity with the refinement of design necessary in the installation of large and relatively more sensitive turbines and lack of experience in the field of high pressure and temperature. After all is said and done, however, it is no more difficult to set and maintain standards for design and operation under these new conditions than it was to work within the lines necessary to secure satisfactory operation under the old. If the power industry is to merit at all popular support and co-operation and, with such support, to achieve the progress and financial return that can readily be had, its engineers must see to it that demands for reliability and continuity of service are met to the "nth" degree.

Safety

It is rather interesting to note, in connection with the matter of safety, that our piping standards have not as yet been revised to provide for the high steam pressures and superheats which are already commonplace in power engineering practice; although it is understood that the American Engineering Standards Committee has under way the preparation of standards for fittings up to 400 lb. pressure. Probably because of the non-existence of standards for the highest ranges, fittings as commercially produced for such conditions show a startling variation in size and design, and this means that the user is going to pay the cost for experimentation, either in the form of excessive prices for over-strong design or in running a risk by installing stuff built too light. The economic advantages to be secured by operation under high pressures and superheats are so much in the minds of forward looking engineers that there has been a tendency to travel too fast, if anything, in experimentation at the cost of the user.

Unfortunately, our governmental agencies and technical organizations are not so financed and constituted that they can conduct the research work necessary as a preliminary to the establishment of standards which will serve to guide the engineer and thereby to reduce cost to the user and ultimate consumer. "Hit or miss" experimentation, although in line of progress, can be a terrific drain upon the pocketbooks of such user and consumer and decidedly wearing upon the nerves of the operating engineer.

Considerable credit is due, however, to the engineers who have pioneered the way in this work and accomplished remarkably successful results with but little penalty in the way of excess cost and it is quite probable that the general average of such work has produced satisfactory results in the way of returns to those who have financed the projects.

Specific recommendations are hardly necessary as to proper provision for safety in the handling of high pressure and temperature steam. Most careful study should be given to ensure that safety valves, valves of the triple duty type and other fittings, are in every way adapted to these new conditions of service and the pioneer has a heavy responsibility placed upon him in this regard.

Possibility of operating troubles due to improper piping design and provision for the absorption of contraction and expansion strains have been mentioned

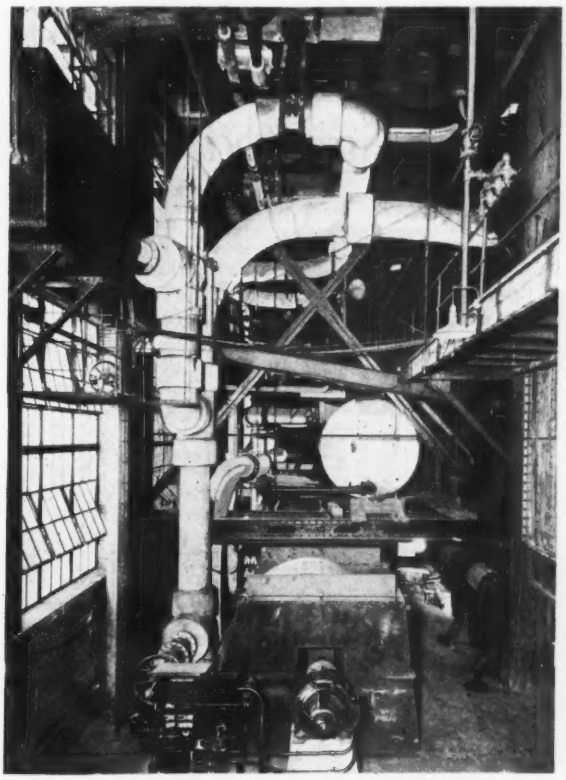


FIG. 2. TYPICAL HIGH-PRESSURE STEAM PIPING

under reliability. It would scarcely seem necessary even to speak of it, but undoubtedly in many instances strains are daily imposed upon steam mains and their fittings beyond a proper safe limit. Hitherto, the factor of safety has been so great, in ordinary engineering practice, that this particular feature in piping design has been of minor consideration and has generally been left to the figuring of an ordinary draftsman. But as engineers come to recognize the economic gain from the use of high pressure steam and such use tends to become commonplace not only in installations but where the greatest danger lies, in application to old lines and mechanical equipment, it is hoped that the user and owner will see to it that the design and operating schemes are engineered by the ablest men who can be secured if value is placed on the safety and lives of employes. One cannot emphasize too strongly the needs of this situation.

If there is one criticism to be leveled at mechanical engineering as a profession, it is that it has permitted the title of engineer to be too freely applied and only too frequently this title is merely a veneer covering absolute ignorance. With changing conditions and the use of steam at high pressures, there will be unquestionably a tendency towards increasing trouble arising from this particular source unless the necessary precautions are taken against it by both the user and the engineer in maintaining and raising the standards of professional practice and organization.

Summary

To summarize, generally, the progress and possibilities in the steam "container and distribution" portion of steam generating equipment, it may be said that ample opportunity is presented for progress in design so as to salvage every possible fraction of a per cent of energy which might otherwise be wasted in order to meet the economic demands of the times; that accomplishment in that direction can be tremendously facilitated by the development and application of measuring apparatus, designed with due regard to certainty and simplicity of operation and to cost, and systematic operation which will ensure that every bit of information derivable therefrom will actually be utilized and applied. Furthermore, particular effort should be made in the design of containers and piping to insure a high standard in the matter of continuity of service and reliability; and the engineer should continually bear in mind that the financial standing and future progress of the power industry is largely dependent thereon. Finally, as advance is made into fields of the unknown, special forethought should be given to the prevention of any condition that might be an element leading to a catastrophe, and that will depend solely upon the professional thoroughness and ability of the engineer in charge.

Undigested Water Makes Steam Vicious

Causes, Effects and Remedies for Priming and Condensation

DRY STEAM is the ideal toward which every power plant engineer strives. It is, however, extremely difficult to attain even when superheated steam is used in the system. For not infrequently it will be found

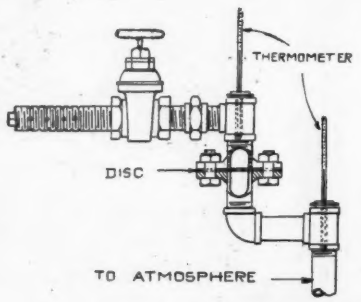


FIG. 1. STEAM SAMPLING NOZZLE

that a pipe carrying superheated steam in the upper part will have wet steam or even a film of water in the lower part of the pipe. So-called saturated steam usually contains a small per cent of moisture which is drops of water brought up with the steam bubbles from the boiler or developed by condensation of steam in the pipe. The former is the chief cause and is due to the fact that, as the steam is formed in the boiler, it collects into bubbles of greater or less size and these break through the surface of the water with a small explosive action throwing up little jets of moisture from the surface, some of which is caught in the steam current and carried forward to the piping.

Evidently, in the case of dense water, which has a tougher surface film, these explosions will be more violent because a greater force is required to break through the surface of the water. Hence, we find that a boiler containing a dense water or one in which a considerable amount of mineral matter is in solution is subject to a greater degree of priming than one where the water is clear. This action is discussed by Mr. Joos in a previous article.

Another cause which will tend to increase the priming is lack of sufficient disengaging surface from which the steam may escape. If there is plenty of surface so that the streams of steam bubbles are not competing for an outlet, there will be less of the explosive action than if there is a violent ebullition. So it is important that in every boiler, particularly if it is to be forced heavily, as is often done in modern practice, there should be plenty of disengaging surface in the steam drum.

Priming caused by dense water can be reduced by blowing down, both from bottom and surface blowoffs, adequate to reduce the density. If the priming is increased by small disengaging surface, the remedy is to carry the water level as low as permissible so as to increase the disengaging surface, and if forcing is responsible, greater boiler capacity must be provided so as to remove the necessity for forcing so heavily.

Effects of Priming

It is the object of a steam boiler to generate dry steam, each pound of which carries the full amount of latent heat of evaporation. To just the extent that water is carried over by the steam, this purpose is defeated, since the hot water has no value in producing power. Priming is, therefore, a cause of wasted heat.

In addition, the drops of water will carry with them in solution mineral scale-forming material and possibly corrosive acids which will deposit in the superheater and piping, causing scaling up at these points and, if acid be present, resulting in pitting and corrosion, which may become serious.

With reciprocating prime movers there is the further effect that any considerable amount of moisture in the steam tends to wash the lubricating oil from the surfaces, thus increasing friction unless an extra amount of lubricant is used. And in the case of steam turbines, there will be the same effect as in the piping, i. e., coat-

ing of the blades and nozzles with scale-forming material and the tendency to corrosion from contained acids; also there is a tendency to cut the blades and nozzles because of the erosive action of water traveling at the high velocities which are maintained in turbine practice.

One other difficulty, which results not only in priming or the formation of wet steam but also makes trouble from overheating, is known as foaming. This differs from priming in that the entire mass of water in the boiler or the upper portion becomes filled with bubbles

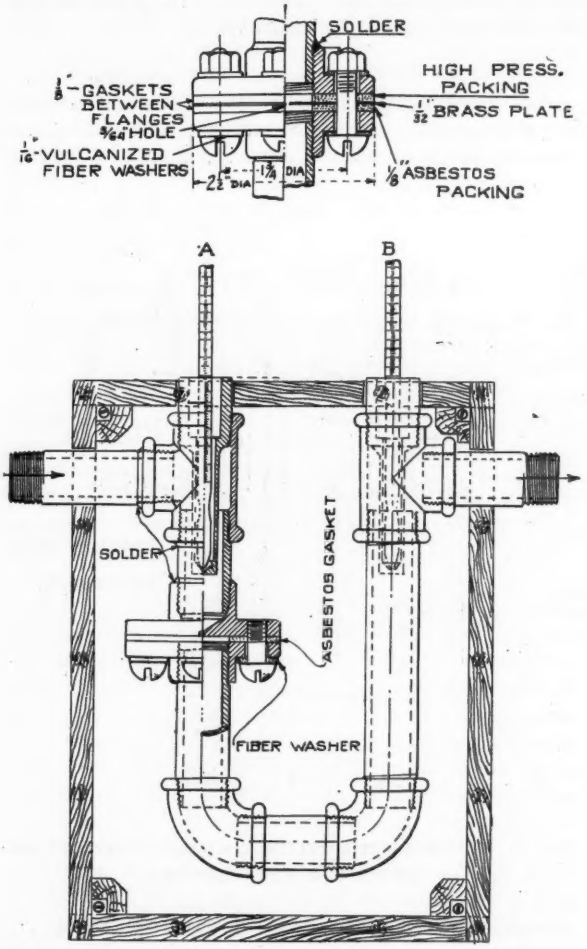


FIG. 2. CONSTRUCTION OF THROTTLING CALORIMETER AND DETAIL OF ORIFICE

much like soap suds. It is usually due to a large amount of suspended matter in the water and comes from the use of too much mechanical reagent in water softening or from the presence of a considerable amount of finely divided scale material which has been loosened from the boiler surfaces.

Generally when foaming is present to a serious degree a test of the water in the boiler will show the presence of excess soda ash or of caustic soda. The remedy is obviously the use of less softening reagent or, if the trouble comes from floating scale particles, a thorough cleaning of the boiler will stop the difficulty.

Test for Wetness of Steam

This is usually accomplished by drawing an average sample of the steam from the pipe near the boiler and determining the wetness by throttling to evaporate the moisture in the steam; or if the percentage of moisture is too great to be determined by this method, a separating device is used which will take out the moisture and this moisture and the steam of the sample, condensed, are then weighed and the weights compared.

One of the most important things in making these tests is to have a correct shape of nozzle and have it in the proper location so as to get a true average sample of the steam in the pipe. Experience has shown that the most satisfactory device is a piece of ½-in. iron pipe closed at the end which projects into the main steam pipe and perforated on the sides with 20 or more ⅛-in.

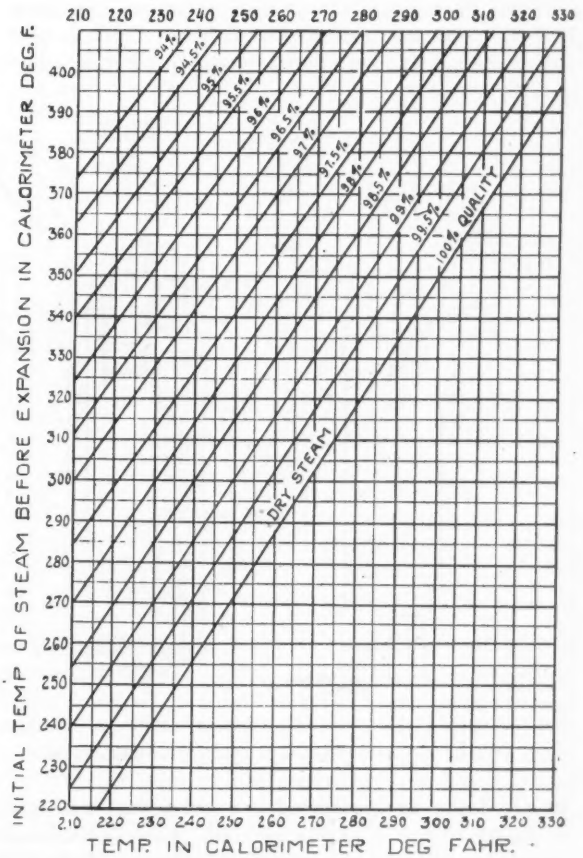


FIG. 3. BARRUS DIAGRAM FOR THROTTLING CALORIMETERS

holes, drilled in irregular or spiral arrangement, the hole nearest to the side wall of the main pipe being ½ in. from that wall and the nozzle being of a length to extend nearly across the pipe, as shown in Fig. 1.

As to location, the nozzle should be placed well away from any pocket where moisture can collect, for testing boiler steam preferably in a vertical run of pipe which comes direct from the boiler, at least 2 ft. above any bottom elbow, since there is always a tendency for water to collect in such an elbow and to run up the outer side of the bend for a distance. If it is necessary to insert the sampling nozzle on a horizontal run, it should be put near the elbow which leads into the horizontal run and set vertically, extending upward from the bottom of the pipe.

Figure 2 shows a throttling calorimeter taken from the power test codes of the A. S. M. E. The cut itself is self-explanatory, the calorimeter being made from ½-in. brass piping and well encased with insulating material to prevent radiation. Steam from the sampling nozzle passes through the orifice which is inserted between the flanges in the left-hand side of the calorimeter and this throttling action converts the moisture into saturated or superheated steam. By taking readings of the thermometers A and B, the wetness of the steam can be read directly from the accompanying chart which was devised by George H. Barrus.

Separating Calorimeter

If the moisture is too great to show a rise in thermometer B above the normal temperature for atmospheric pressure, the separating calorimeter must be used. For this an instrument made of pipe fittings, as shown in Fig. 4, can be constructed or a commercial instrument as shown in Fig. 5 may be secured. For the homemade apparatus, the weight of moisture gathered in the separator is determined either by weighing or from previous calibration of the gage glass, and the steam escaping from D is condensed in a pail or barrel of cold water and its weight determined. The percentage of the moisture will then be the weight of the water collected in the separator divided by the sum of the weights of the water in the separator and that condensed from outlet D.

In the commercial instrument the same process of separation is used but the gage glass is graduated to show hundredths of a pound at the temperature corresponding to ordinary working pressures and the pressure gage shows the pressure in the outside jacket. The nozzle N is calibrated so that the flow of steam at given pressures is known and by consulting a chart furnished with the instrument the flow at any given pressure can be determined direct, or the gage may be calibrated in pounds flow per minute.

In the case of the instrument made from pipe and fittings, it will be necessary to determine the radiation loss even when the instrument is well covered with insulating material. This can be done by using two instruments of this type connected in series. The moisture collected in the second will then be that due to its radiation, which will, of course, be the same as that for the first instrument. If there is doubt about the removal of all moisture from the steam by the first instrument, a small throttling calorimeter can be attached between the two to determine the moisture in the steam coming from the first separating calorimeter.

Wetness Testing for Low-Pressure Steam

For pressures under 25 lb., the separating calorimeter will not take out all the moisture, and it is necessary to use a combined separating and throttling calorimeter as shown in Fig. 6. For this, it will be noted, that a special type of sampling nozzle is used. Steam is passed first into the separating chamber where moisture is thrown out and drawn from the ½-in. drain into a pail of cold water to be weighed. The balance of the steam passes through a throttling calorimeter in which headings are taken of the pressure and temperature, and then goes to the condensing apparatus. The total moisture in the steam will then be found as follows: Multiply the weight of dry steam condensed after passing through the throttling calorimeter by the per cent dryness of the steam as shown by that calorimeter. Divide this by the sum of the weights of the steam condensed and of the moisture drawn from the separating calorimeter. If there is question about a considerable amount of radiation effect in this instrument, it can best be determined by letting the apparatus stand for a time with the lever cock between the two calorimeters closed and determining the amount of moisture which gathers in the separating chamber.

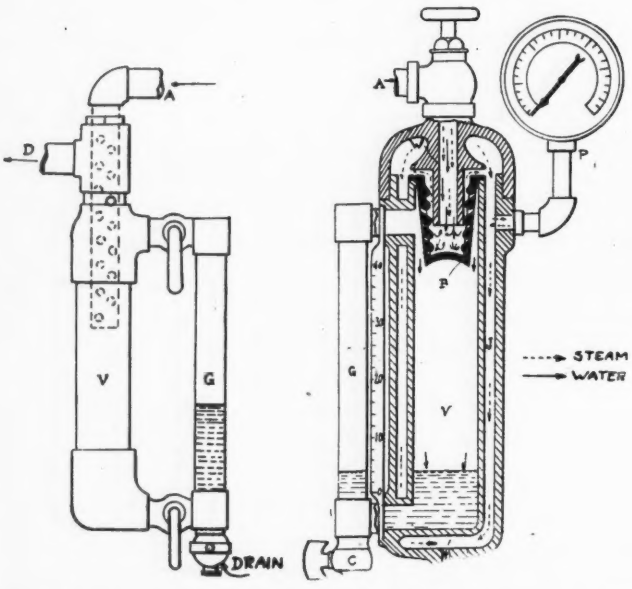


FIG. 4. SEPARATING CALORIMETER OF PIPE AND FITTINGS
FIG. 5. COMMERCIAL SEPARATING CALORIMETER

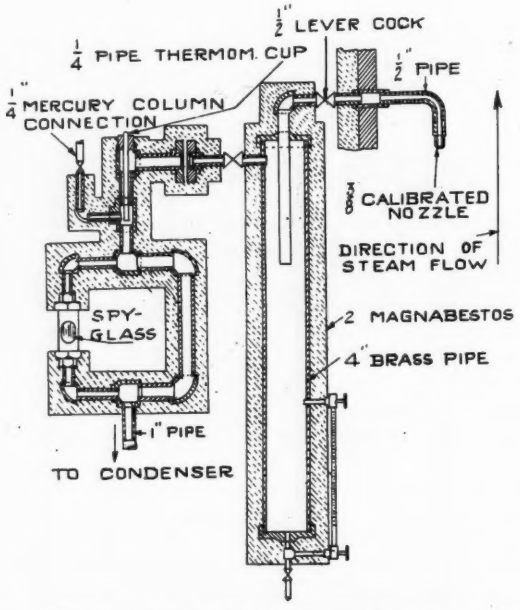


FIG. 6. COMBINED THROTTLING AND SEPARATING CALORIMETER FOR LOW PRESSURE

Barrel Calorimeter

Where a single check up test is required and no other type of calorimeter is available, what is known as the barrel test may be used. A barrel of water is placed on a platform scale and steam from a sampling nozzle is led into it, the open end of the tube discharging below the surface of the water. The weight of the water and barrel and temperature of the water are taken and also the pipe leading from the sampling nozzle should be blown clear of all moisture and condensate before starting the test; then steam is allowed to flow into the water and be condensed, the water being continuously stirred so as to be kept at uniform temperature throughout. Steam is allowed to flow until the temperature of the water in the barrel is as much above that of the room as it was below that temperature at the start. Steam is then shut off, the final weight of the barrel and water is taken and the final temperature. The quality of the steam may then be determined as follows:

Divide the difference in sensible heats of the liquid at the beginning and final temperature by the heat of evaporation of steam at the pressure in the steam pipe. Multiply the original weight of water in the barrel by the difference between its initial and final temperatures and divide this by the gain in weight of water during the experiment and by the latent heat of the steam at the pressure in the pipe. The sum of this final quotient and that from the first computation will give the quality of the steam. This test is only approximate and should be used only to get an indication of the condition of the steam.

Dry Pipe

Besides the methods already indicated for reducing priming such as using clean water, blowing down, and maintaining a maximum area for disengagement, it is often considered advisable to use either a baffle near the point where the strongest up current of water and steam rises in the boiler to catch the spray from boiling at that point, or to use a collecting pipe which will act as a separator inside the boiler. This collecting pipe illustrated in Fig. 7 is simply a length of pipe capped at the ends and drilled with holes sufficient to give an inlet area somewhat greater than that of the steam nozzle. The whipping action of the steam in passing into these openings, as well as the slight wiredrawing, will tend to clear the steam of moisture before it leaves the boiler.

Methods Used for Measuring Boiler Performance

In order to keep a plant up to its maximum effectiveness, it is necessary to know what the boilers are doing. The ultimate end for which we are striving is the greatest amount of steam made per dollar of cost. In order to know how nearly this is being effected, it is essential to know how much steam is being made as well as the cost for fuel, labor, plant upkeep and overhead expense.

Methods commonly used for measuring boiler output are weighing or measuring tanks, water meters and steam-flow meters. On account of the inconvenience of the operation and the great size of tanks needed, it is unusual to use tanks except during a boiler test.

For everyday use, a more convenient system is installation of water meters, of which there are four general varieties. One is the type of meter which measures the volume of the water flowing through it either by piston displacement, an oscillating disk or a turbine wheel, the strokes of the piston, the oscillations of the disk or the revolutions of the wheel driving a train of gears which operate as a speed counter. The second type is the venturi which measures the flow by means of the difference in heads between points in a contracted nozzle inserted in the feed pipe. The third method is that of the bucket type of volume meter operating practically on the principle of the over-shot water wheel, but carefully designed so that each bucketful will be of exactly the same volume. And the fourth type is that of the weir, usually of V notch form, which has been highly perfected by a number of different makers. The objection to any meter which measures volume is that correction for any change in temperature of the feed water must be made because the weight of a given volume will vary with the temperature, but provision has been made in most of the types for taking care of this correction.

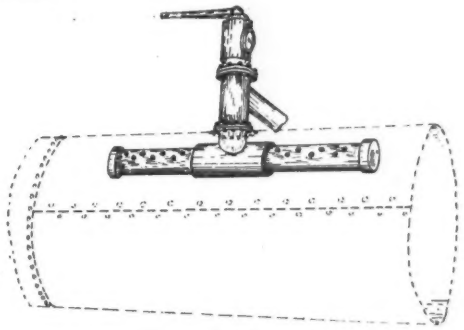


FIG. 7. INTERNAL DRY PIPE

One other difficulty with the piston, disk or turbine type is that the moving parts are usually made of hard rubber. These are considerably affected by high feed water temperatures, resulting in a loss of accuracy. In the venturi meter there are no moving parts in the meter itself. The water passes through a contracted throat in which the velocity is increased and the pressure reduced and afterwards loses velocity and gains pressure as the area of the pipe is increased. Connections to the points of ordinary and reduced pressure are made so that the variation of difference with the flow through the throat will actuate a recording mechanism.

Pitot tubes may also be employed but must be placed in a length of straight pipe not less than three feet plus five diameters from a bend. The pitot tube is of the usual form and is generally connected to a mercury tube having a float resting on the upper surface of one end of the mercury so that the rise and fall of this float with the variation of the pressure in the pitot tube will serve as a guide to the volume of water flowing.

In the case of the weir meter, the water is passed through a V notch at some point in its course, often in an open feed water heater, and the height of the water in this notch is recorded by means of a float placed in a chamber back of the weir. The float operates a pen mechanism which records on a chart its position and from the equation for the flow of water over a V notch the chart can be graduated to read in pounds or in cubic feet per minute. The chart is driven by clock work. In using this type of meter, care must be taken that the flow is steady and regular and that in the cham-

ber back of the weir where the float operates there is no disturbance of the surface which might result in wave action. When properly designed and calibrated, the indications are accurate and the operation is very simple. There must, however, be correction either by the mechanism itself or by calculation for the variation of the weight of a given volume of water with temperature.

In the bucket type of meter, which is represented practically by a single device, the operation is as indicated in Fig. 9. Water enters the bucket and by its weight revolves the wheel, revolution after a certain distance be-

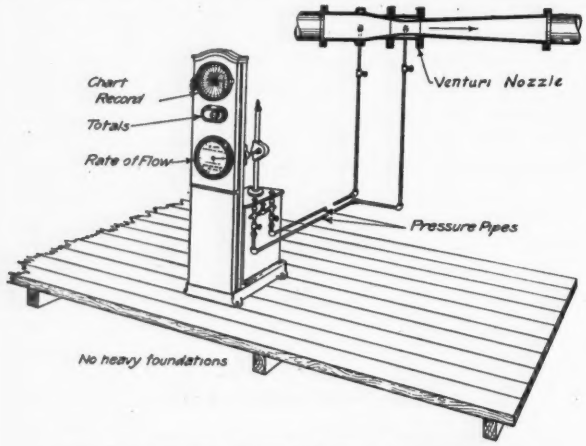


FIG. 8. VENTURI NOZZLE METER AND RECORDER

ing accompanied by a spill-over to the following bucket, so that at the point where the water begins to drain from the small end of the bucket, a definite volume will be retained. Evidently, in the drawing shown, six buckets will be filled and emptied with each revolution of the bucket and by the use of a properly calibrated speed counter the volume of water passing can be recorded.

Steam Flow

Objection to the measurement of feed water as an index to boiler performance is that any leakage of the

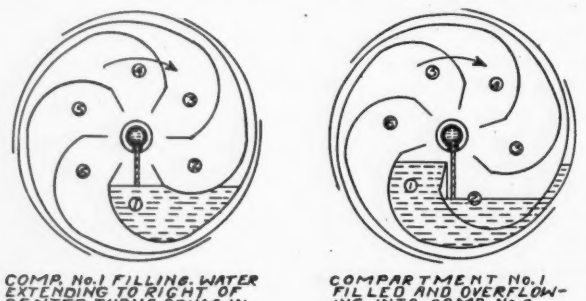

COMP. No. 1 FILLING. WATER EXTENDING TO RIGHT OF CENTER TURNS DRUM IN DIRECTION OF ARROW
COMPARTMENT No. 1 FILLED AND OVERFLOWING INTO COMP. No. 2

FIG. 9. BUCKET TYPE WATER METER

piping or fittings between the meter and the boiler or any withdrawal of water for any purpose between those points will cause an error in the record. Also any considerable amount of priming will give incorrect indication, since the water which goes over as drops of moisture in the steam will be measured in the feed water, but will not be evaporated into steam. For this reason and also because it is often desirable to measure the distribution of steam to different departments and for different purposes, the steam-flow meter is much to be preferred as a method of measuring boiler performance. These meters measure the difference of pressure in a flow nozzle, orifice tube or pitot tube, and vary in the details of mechanism. They are of sufficient importance so that they will be taken up in a special article in this section.

Waste in the Steam System

Chief wastes which occur in the steam system are from leakage, from radiation and from the blowing off of steam or the blowing down of water. Leaks are unfortunately often neglected until they become of considerable amount. It is only necessary to consider that a hole ⅛ in. in diameter will blow 2500 lb. of steam at a 150-lb. pressure to the atmosphere every 24 hr. to realize that even small leaks are costly.

In addition to the waste of steam, and therefore of fuel, which such leaks involve, there is great likelihood of damage to the pipe covering and to machinery or goods which may be in line with the leakage. Regular careful inspection and repair of piping and packings

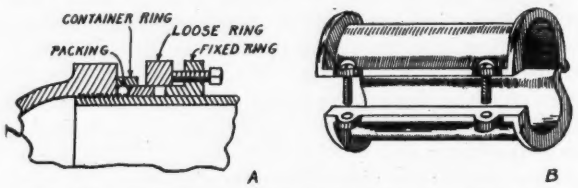


FIG. 10. EMERGENCY REPAIR CLAMPS FOR PIPE AND FLANGE LEAKS

will repay for the inconsiderable cost involved. Where it is difficult to make a permanent repair of a leak, temporary repairs can be effected by the use of pipe clamps and joint clamps with soft packing, two forms being shown in Fig. 10.

Radiation is the loss occasioned by lack of provision of insulation. Experiment has shown that three thermal units are lost per hour from each square foot of pipe surface for each degree difference in temperature between the steam and the outside air. If this be reduced to a cost in dollars per year it will be found that for one square foot of pipe carrying steam at 200 lb. pressure, there is a loss of 50 cents a year based on a coal cost of $8 a ton in the furnace and evaporation of 7 lb. of steam per pound of coal. It is easily seen that good insulation of all surfaces is a profitable investment. Just how far it pays to go is another matter. Evidently beyond a certain thickness of covering the cost for additional covering will not be justified by the additional saving. It has been found by L. B. Macmillan, in a series of tests which were carefully conducted for the usual forms of pipe covering, that the desirable thickness for temperature difference between the steam and the room is as given in Fig. 11.

Loss from blowing down water from the boiler and from allowing steam to blow off through the safety valves is another item that should be carefully watched. Blowing of the safety valve is usually avoidable and always undesirable. The waste of steam is indicated by what has already been said about the loss through leaks but it should be remembered that a 2½-in. valve at its minimum discharge capacity will blow off 2354 lb. of steam an hour at 200 lb. pressure, which is equivalent to waste of 5½ lb. of coal per minute.

Blowing down is, of course, necessary in order to remove impurities and keep down the density of the water in the boiler, and there should be no hesitation about blowing down the boiler as often as is necessary to get proper operating conditions, but blowing down

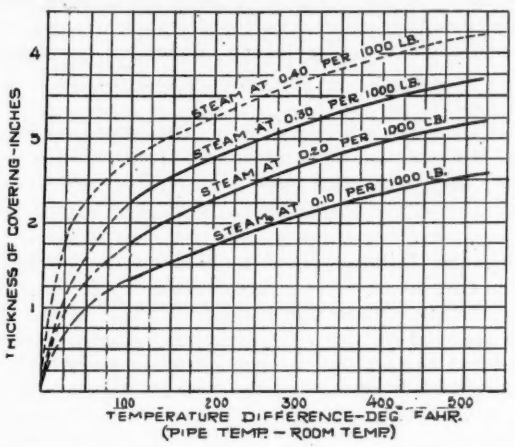


FIG. 11. PROPER THICKNESS OF 85 PER CENT MAGNESIA PIPE COVERING

more frequently or to a greater degree than is necessary involves a waste of large amounts of fuel. An 18-ft. by 60-in. boiler blown down 3 in. at 200 lb. pressure will waste about 3,300,000 B.t.u., which is equivalent to 250 lb. of ordinary bituminous coal.

Effects of Wet Steam

Scaling and corrosion of piping and turbine blades have already been mentioned but there is also a bad effect on valves because the presence of scale-forming minerals in wet steam and of rust scale formed by corrosion and pitting, not only prevents valves from closing tight thus resulting in leakage, but also tends to cut the faces of the valves and seats, thus producing a leakage which can only be overcome by regrinding or by replacing of the operating surfaces.

Another effect of wet steam is that it will increase the condensation due to radiation from the steam pipe and other containing vessels. Dry or superheated steam gives up its heat but slowly to the surfaces surrounding it but wet steam conveys heat much more rapidly because of the closer contact of the particles of water in the steam and the surfaces, so that the condensation becomes a rapidly cumulative effect.

Where condensation becomes considerable, especially if there be pockets or a vertical riser turning up from a horizontal run, water is likely to collect until a sufficient quantity has accumulated to form a slug filling the entire pipe. This will then become a piston of water carried forward through the length of the pipe by the flow of the current of steam until it strikes an obstruction such as a bend or a valve when it will strike a hammer blow. This result, known as water hammer, may have sufficient force to injure or even to rupture the pipe and fittings.

If water in any quantity be carried over into a reciprocating prime mover and is caught between the piston and the cylinder head, great damage will, of course, result, generally breaking either the cylinder head or the connecting or piston rod; and, if the prime mover be a steam turbine, the carrying over of the slug of water may result in stripping a number of blades from the wheels.

In industrial processes the presence of moisture in the steam, especially if it is carried over in the form of priming from the boiler and contains mineral impurities and possibly acids, may result in the destruction or injury of large quantities of the goods being manufactured.

Removing Water from Steam

Ample drips should be provided particularly at those points where water can accumulate either because of a pocket caused by the run of the pipe, an upturn from a horizontal to a vertical run, reduction from a large to a small size of pipe, or a vertical drop pipe with a valve following it either in the vertical pipe or in the horizontal run beyond. Any of these conditions will permit the accumulation of a quantity of water while steam is flowing, or while the flow of steam may be stopped but the pipe filled with steam. Some of the places where drips should be provided are indicated in Fig 12. Of course drips should be provided for the cylinders of all reciprocating prime movers, so that the

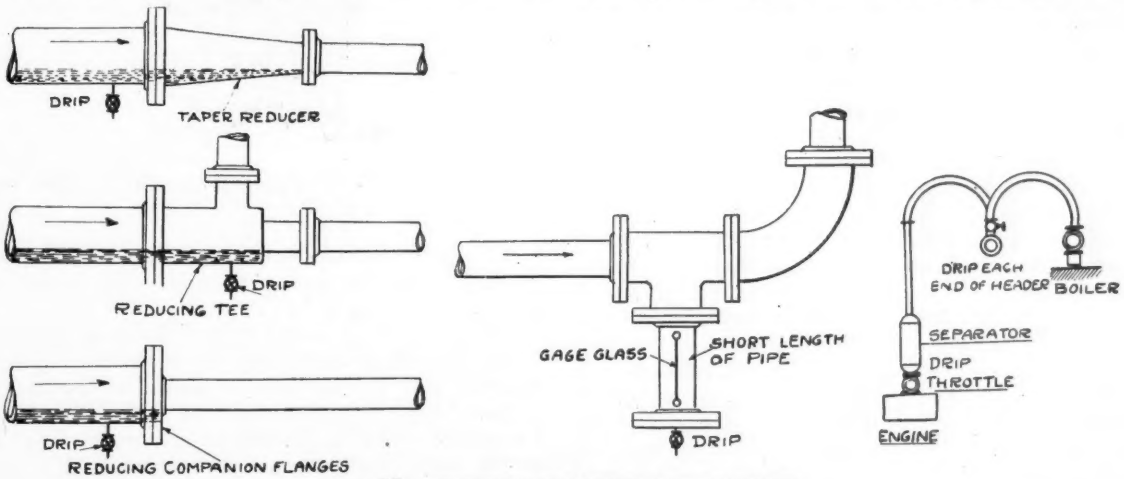


FIG. 12. PROVISION FOR DRIPS AND DRAINAGE

moisture which is formed when starting up may be quickly blown out.

Traps

Frequently it is desirable to provide either a central reservoir into which all condensation may be drained, or a reservoir for each drip, where water may accumulate to be drained at regular intervals by hand operation. If, however, there is a considerable and steady discharge of condensation from the drip or drips it is desirable to have the drainage automatic and continuous and in such case a trap should be provided which will discharge either to atmosphere or to a hot well, according to the condition of the condensate. These traps may be of any of the several types—float, bucket, expansion or tilting—different types being adapted for different uses and locations. Some of the typical forms are shown in Fig. 13.

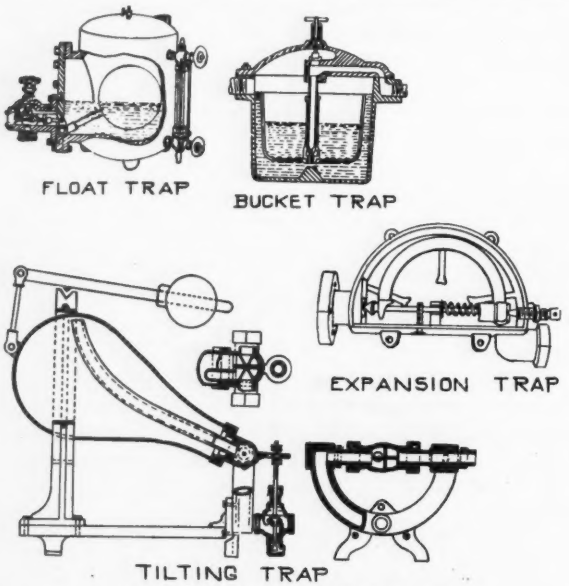


FIG. 13. TYPES OF STEAM TRAPS

Whatever type of trap is used it should be so located that it can be continuously inspected and easily repaired. Putting a trap in a dark hole where no one can get at it and where it will have little or no attention, is poor economy; for the best trap in the world will gradually get out of order under such conditions and either will not take care of the water which it is supposed to handle or will get in such condition that it will pass not only water but steam, thus becoming a source of continuous leakage. Discharge from traps should be such that the water will drain from them readily in order to give free action of the trap, and the piping should be so arranged that the trap is bypassed and the water may be carried around it during the time when it is undergoing inspection or repairs.

Valves should be ground regularly and the valve seats replaced as often as may be necessary, according to the service in which the trap is operating, to keep the trap working properly and seating tight.

Separators

Where there is but little moisture in the steam or where the moisture is distributed throughout the steam and does not accumulate in the bottom of the pipe so that it can be caught by drip pipe drainage, it is necessary to pass the steam through some apparatus which will remove this moisture. For this purpose the separator is adapted, being usually of one of two forms; the baffle plate type, which causes the steam to strike against a series of baffles to which the moisture adheres, or the centrifugal type which gives the steam a whirling motion, throwing the moisture to the outside of the chamber where it is caught by corrugations and carried to a receiving chamber.

If oil must be removed as well as water, as is usually the case in exhaust steam from reciprocating units, the baffle plate type seems to be effective but it is necessary that the baffles be washed with a spray of cold water; otherwise the oil will stick to the baffles and will be picked up and carried on by the steam current or else will accumulate to such an extent that no more oil can find lodgment on the baffles. Also it is essential for either steam or exhaust separators that provision be made for carrying the condensation away from the body of the separator to a compartment into which the steam does not enter, for if the condensate

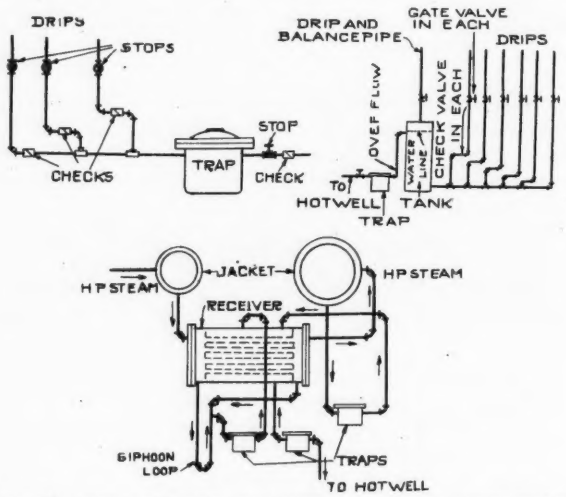


FIG. 14. USE OF TRAPS FOR TAKING CARE OF DRIPS FROM PIPING AND MACHINERY

be left where the steam current can come in contact with its surface, the dry steam will again pick up moisture and carry it forward.

Steam separators should be located as near as possible to the apparatus which they are designed to protect. Whether they be used in a horizontal or vertical run seems to make little difference, but it is well to install a separator in the line leading to each prime mover, and in the main feeding auxiliary appartus at a point where it will protect the branch lines from any condensation that may accumulate in the main line.

Even in using superheated steam it is often found advisable to introduce a separator ahead of the prime mover for, as before stated, it is possible to have superheated steam flowing in the upper part of a pipe which also carries a film of water or even a thin stream along the bottom. Where separators are used, they may be drained the same as drips either by providing a large receiving chamber which is emptied periodically by hand operation or by allowing condensation collected to run to traps which automatically drain it away. In any

case, sight glasses should be provided so that inspection will show whether condensation is accumulating in the separator chamber and like all other apparatus about the steam plant the separator should be inspected internally as well as externally at periods of at least a year, and oftener if found necessary, in order to make sure that the passages are free and clear and all parts of the apparatus in good condition.

It is well also to have careful inspection of horizontal runs of piping at regular periods to make sure that they are level or are inclined slightly with the flow of the steam so that the moisture will tend to go with the steam to a point where it can be readily taken care of. Piping which inclines backward or which has a sag tends to hold the water in the pipe and thus to throw a greater percentage of moisture into the current of flowing steam. If water gets into the pipe it is best to let it go forward with the steam to a proper drip point or to a separator and then take it out, thus removing the cause of the trouble as readily as possible.

Types of Feed Water Meters

STEAM FLOW OR FEED WATER FLOW READINGS ARE NECESSARY TO KEEP TRACK OF THE OUTPUT OF THE BOILER PLANT

IN ANY plant where any attempt is made to keep track of the boiler room expenses and output, two fundamental records are needed; one is the amount of coal consumed and the other is the amount of steam generated in a given time. This latter quantity may be measured by either a steam flow meter or by a feed water meter or by both, in which case one acts as a check on the other.

There are in general three different principles used in the measurement of water flows. The first is by means of a weir, the second by measuring the pressure drop across a restriction in the pipe through which the water is flowing, and the third is by purely mechanical means, i. e., the water flowing through the line is made to operate a turbine or some form of water motor.

Flow of water over a weir notch follows certain definite laws. For a given shape and size of notch the quantity discharged bears a certain relation to the head causing the flow. If then, means are provided for measuring this head, this measurement may readily be translated to give flow. When the flow curve for any shape notch is known it is possible to use the head above the notch to record continuously the rate of flow and also to integrate it so that total readings may be taken from time to time.

With a V-notch meter at low flow there is a proportionately greater head to deal with, the power to operate the recording mechanism is greater and consequently greater accuracy is possible. In one type of V-notch meter, that shown in Fig. 1, the flow is indicated by pen arm actuated by the rise and fall of two floats of different design, on a lever arm. As the water level rises the short displacing member rises partly with the water while the longer one is immersed deeper into the water until the buoyant effects are balanced. These two displacing members are so shaped in accordance with the flow curves that the indicator or pen arm moves in proportion to the flow and not the head. By means of a clock operated chart a record may be kept of the pen movement and in addition the flow may be totalized by integrating gearing. The curve of the flow over a V-notch is such that at say 25 per cent of full flow, the head is 57 per cent but the floats automatically adjust themselves to read 25 per cent. At 50 per cent flow the head is 76 per cent and at 75 per cent flow the head is 90 per cent, but in each case the pointer indicates the flow direct.

When water flows through a tube containing a contraction such as in a venturi shaped tube, there is a change of velocity from the full to the contracted section and with it a corresponding change of static pressure. The loss of pressure at the throat section increases as the square of the velocity and consequently also as the square of the quantity of flow. This pressure difference may be indicated on a mercury manometer calibrated to read flow direct or by means of floats and lever attachment may be made to actuate an indicator needle. The dial covered by the indicator is calibrated to read flow. As the distances between equal increments of flow on the dial are not equal but vary as the square of the flow, it is necessary, in order to integrate the flow, to use a cam to operate the recording mechanism.

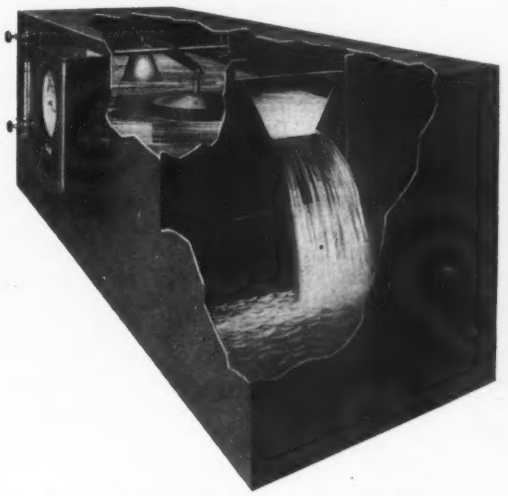


FIG. 1. V-NOTCH TYPE FEED WATER METER

In Figs. 2 and 3 are shown two types of mechanical meters. The mechanism shown in Fig. 1 is practically a hydraulic turbine pump whose action is reversed. Water enters the main casing through a strainer, the column then divides flowing on both sides of a double wheel carrying two sets of vanes, it passes through the rotor and into the volute casing and thence out. Water in passing through the rotor imparts to it a velocity that is proportional to the velocity, and therefore the quantity, of flow. The motion of the rotor is transferred through suitable gearing to integrating mechanism or counter which is calibrated to read total flow in any desired units.

The meter shown in section in Fig. 3 is of the positive displacement type. In the position shown, water enters say from the right-hand side and passes to the upper side of the disc piston causing it to rock to the left and at the same time to rotate about a vertical axis. As this motion progresses the inlet port is closed

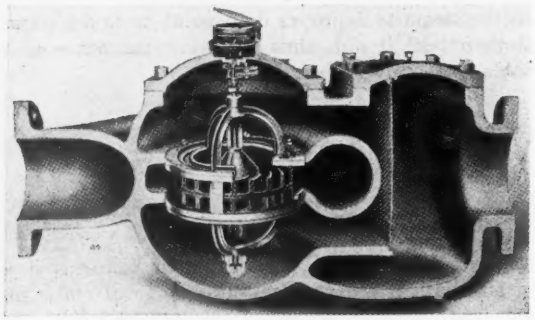


FIG. 2. TURBINE WHEEL FLUID FLOW METER

and a discharge port on the left side is opened. At the same time an inlet port under the disc on the right side is opened and the disc starts to rock to the right, at the same time maintaining the rotation about the vertical axis. The resultant motion may be described as one of mutation, i. e., it is the motion of the axis of a top as it swings about around its point of support.

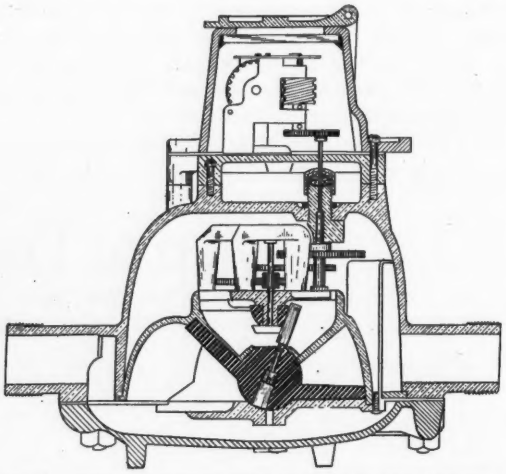


FIG. 3. DISPLACEMENT TYPE WATER FLOW METER

This motion is transmitted to a system of gearing in an integrating mechanism that is calibrated to indicate total flow in gallons or cubic feet as may be desired.

Methods of Measuring Steam Flow

DIFFERENTIAL PRESSURE IS MEASURED BY MANOMETER IN FLOW METERS; METERS SHOULD BE PROPERLY INSTALLED AND CARED FOR

NEARLY ALL meters for measuring water or steam flow in pipes are based on the principle of measuring a difference of pressure created by a change of velocity of the water or steam. The only exceptions are displacement and turbine meters as used in residiences and variable orifice meters.

This change in velocity must be created by some means and this is done through the use of a flat plate orifice, venturi tube, flow nozzle, or pitot tube, as shown in Fig. 1.

For the measurement of this pressure difference, a mercury manometer, or U tube as it is sometimes called, is used. Such U tubes are shown diagrammatically in Fig. 1 and the effect of the variation of pressure on the mercury column can also be seen.

There is also another method of creating a pressure difference which is in use. This method makes use of the principle that fluid or steam passing around a short right angle bend will be thrown toward the outside by centrifugal action. As a result the pressure is higher on the outside and a measure of the pressure difference, varying due to different velocities, will give a measure of the flow.

To translate the movement of the mercury column into terms of steam or fluid flow has been the problem of flow meter development. Several schemes have been used, such as a float which transmits its movement to a ratchet and pinion; the use of electrical contacts which are shorted out by the mercury column and the measurement of the resistance left in the circuit is another method. A recent development uses a tilting U tube which transmits its angle of tilt into terms of flow by a suitable mechanism.

Since the flow of both steam and a fluid conforms to the same general laws, the same meter may be used for both purposes. It is necessary, however, to protect the

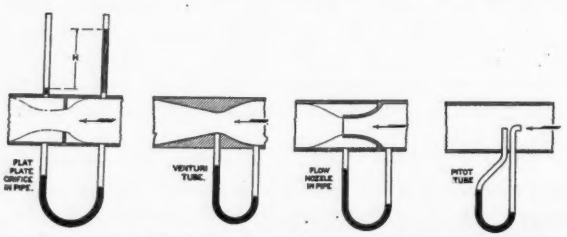


FIG. 1. FOUR METHODS OF CREATING A PRESSURE DIFFERENCE BY MEANS OF A CHANGE IN VELOCITY

internal mechanism of the recorder from direct contact with steam, hence the pressure transmitting tubes are filled with water. The level in both tubes must be the same at all times and small condensers are used to make up this head as the water level drops in one pipe and rises in the other, due to a change in level of the mercury. Small reservoirs are sometimes used in such a way that the pressure transmitting pipes will always be full of water.

METER DEPENDING UPON BELL SHAPED PLUNGER IN MERCURY

IN THE METER shown in Fig. 2 the higher and lower pressures from the inlet and outlet sides of the orifice are applied through pipes marked high pressure and low pressure. The higher pressure is conducted through the center tube into the space within a mercury sealed bell. The low pressure is conducted through the casing

cover to the interior of the casing which is subjected to the full pipe line pressure of the steam being metered.

It will be noted that the bell is entirely closed except at its lower end, which is sealed by the mercury contained in the reservoir. As the high pressure, applied through the tube to the space within the bell, is in excess of the low pressure applied outside the bell, there is a tendency to force the bell upward by an amount equal to the differential pressure. This movement of the bell is transmitted to the recording mechanism by a forkel level which engages a squared section of the spindle. By properly proportioning the shape of the bell the movement has been made directly proportional to the flow.

Magnets Actuate Meter

In the flow meter illustrated in Fig. 3 the change in level of the mercury rotates a magnet by means of

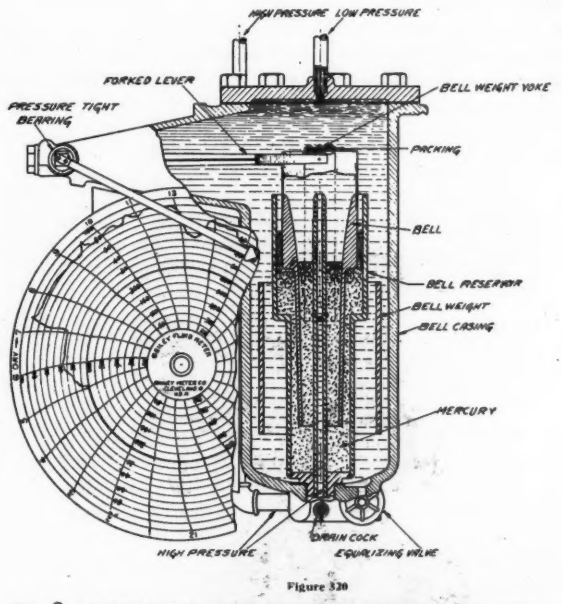


FIG. 2. MECHANISM OF FLOW METER EMPLOYING BELL SHAPED PLUNGER FLOATING IN MERCURY

a float, rack and pinion. The motion of this magnet is transmitted magnetically to an outside magnet carrying the indicating pointer and pinion which engages with the large gear sector driving the recording pen.

Meter Uses Tilting Manometer

One of the recent developments in the flow meter field has been the use of a tilting manometer for the transmission of the pressure differential to the recording mechanism. This principle in a meter was fully described in the Oct. 15, 1921, issue of Power Plant Engineering. A view of the operating mechanism is shown in Fig. 5.

Connecting the orifice pressure pipes with the tilting manometer was a problem which required considerable investigation before a practical solution was obtained. This was taken care of by means of torsion tubes. These tubes are 6 in. long, made of hard brass, and will stand a pressure of 1500 lb. At one end the tubes are inserted in a stationary block holder while at the other end they are fastened to a holder mounted on the tilting frame. The tubes are so located that the axis of the knife edge of the manometer is exactly midway between the center line of the torsion tubes.

When the U-tube tilts through its small angle of operation, these tubes are twisted. At first thought it would seem that considerable force would be required to twist these tubes, but such is not the case. The small

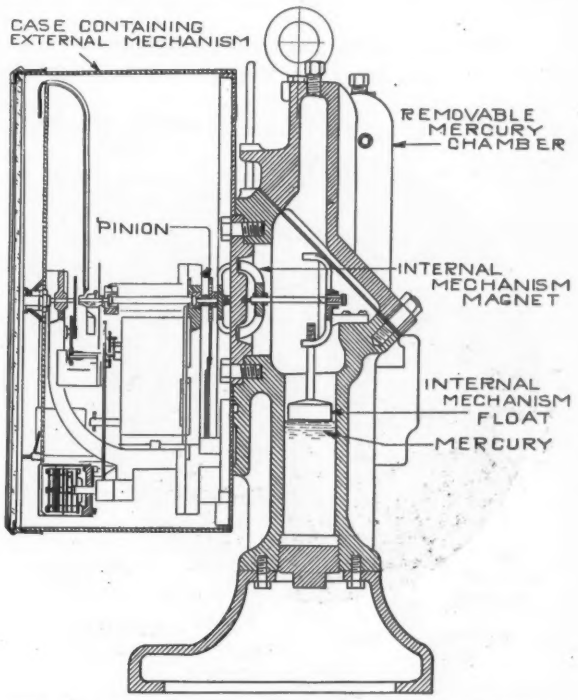


FIG. 3. METER WITH MAGNETIC OPERATING FEATURE

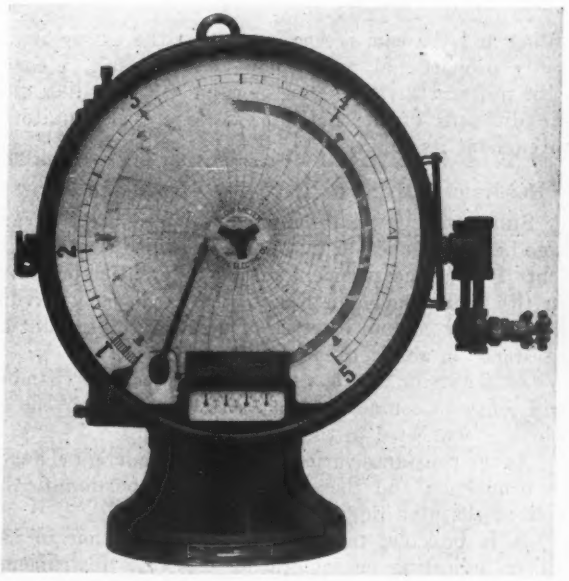


FIG. 4. RECORDING CHART METER SHOWN IN FIG. 3

force which is required is compensated for by the cam, which also has functions as shown in the following paragraphs.

As the difference between the pressures on the two sides of an orifice varies as the square of the rate of

flow, the movement of the tilting U-tube would not be uniform throughout the range of flow, unless some method of correction were adopted. It is for this purpose that the cam shown in Fig. 5 has been utilized.

This cam is mounted on the U-tube beam and bears against a flat metallic strap which is kept taut by a weight and guided by a stationary sheave. As the U-tube tilts, an increasing resistance is offered to the

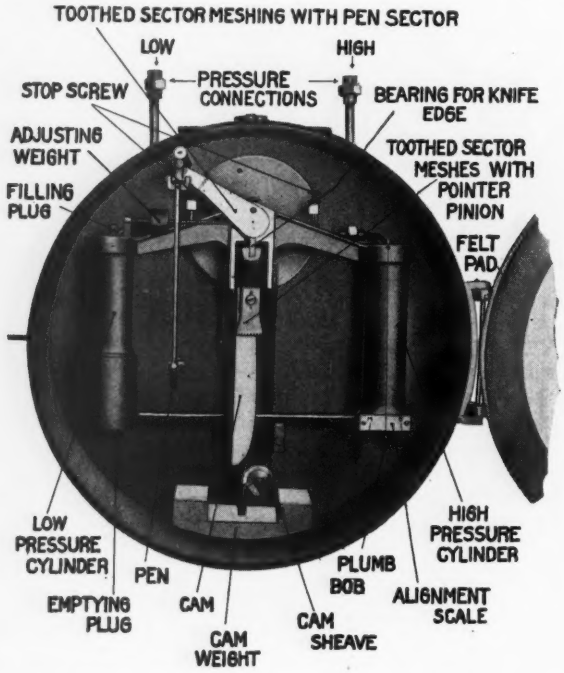


FIG. 5. METER EMPLOYING TILTING MANOMETER

tilting and the cam is so shaped that the tilting is directly proportional to the flow. As a result, a chart with uniform divisions can be used for recording and the divisions of the indicator scale are also uniform throughout its range.

Electrical Methods Used for Measuring Flow

Since mercury is a conductor of electricity advantage has been taken of this point to utilize electric currents for the measurement of the differential pressure. In the meter shown in Fig. 6, this is done by having the mercury column increase or decrease the amount of resistance in an electrical circuit.

As shown in Fig. 6, the mercury rises in a chamber and comes in contact with a series of rods, each one of which is connected in the resistance circuit.

As the resistance varies, the electrical current changes in proportion and therefore also in proportion to the flow in the pipe line.

It is possible, then, by proper calibration to use either indicating or integrating electrical instruments to record the flow.

In another meter which makes use of a similar principle the differential pressure is obtained by taking advantage of the fact that the pressure in the outside of a right angle bend is greater than that on the inside, due to centrifugal action.

An inclined mercury tube is so arranged that the rising and falling of the mercury changes the amount of resistance in an external circuit. The measurement of this resistance on the Wheatstone bridge principle gives an indication of the steam flow. A galvanometer is so used that its deflection closes the circuit to a small motor which operates a rheostat and balances the other side of the bridge when a change in steam flow causes a change in level of the mercury. The rheostat arm is therefore actually the pointer of the indicating meter. A mechanical integrating mechanism is also used.

Installation of Flow Meters

One of the most important points connected with the installation of flow meters is the location of the differential pressure producing element. There are no definite rules which can be established regarding the length of straight pipe on the inlet or outlet side of the orifice as a great deal depends upon the velocity of the flowing steam and the nature of the fitting or section preceding the run.

For low velocities of 2000 ft. per min., the orifice can be located in almost any flange even with an elbow or valve on the inlet side of it. With normal steam

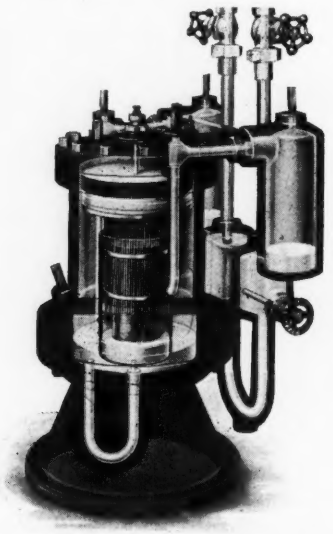


FIG. 6. CHANGES IN ELECTRICAL RESISTANCE USED TO MEASURE FLOW

velocities of 6000 or 7000 ft. per min., it is desirable to have at least five diameters of straight pipe on the inlet side, although this also depends on the fittings or disturbance which precedes the straight run. For velocities of higher than 12,000 ft. per min., a distance of at least 10 diameters of straight run on the inlet side is recommended, preceded by a suitable fitting and five diameters of straight run on the outlet side of the orifice. Of course it is advantageous to use a longer run of straight pipe if this is possible.

One condition met with is a swirling flow caused by an elbow or a tee and especially a Y fitting on the inlet side of the orifice, even at a considerable distance from it. This condition may be remedied by the use of a straightening vane inserted in the pipe. Such a vane is made of sheet metal and shaped to make the flow parallel to the axis of the pipe by dividing it into several small streams. The area of the pipe is only slightly restricted and causes little drop in pressure.

Orifice elements or flow nozzles are located between a pair of pipe flanges and if flanges are not located to give the proper length of straight run it is necessary to take down a section of pipe and insert a pair of flanges. It is usually considered satisfactory to install the orifice between the flanges connecting a straight run of pipe or bend with a radius of at least 13 pipe diameters. If it is not possible to obtain the straight run down stream from the orifice, the down stream flange may be that of a gate valve, provided the gate valve is kept full open during operating periods. Another practicable location is between the flanges on a straight run of pipe and a flanged elbow, with the elbow down stream.

Any flow meter will read high on a pulsating flow such as is caused by the action of a reciprocating engine or pump. In such a case, it is necessary to provide some means of reducing the pulsating effect. One manufacturer recommends the use of a receiver, or locating the orifice so far from the unit that the length of pipe acts as a receiver. Another method sometimes used is to place a throttling orifice about halfway between the meter orifice and the source of the pulsations. This will introduce a certain drop in pressure which corresponds to the drop caused by friction in a long pipe.

These methods do not eliminate the pulsations entirely, but tend to smooth out the peak flow and no flow periods and hence produce a variable flow which can be recorded with reasonable accuracy.

It is usually recommended that the recorder be placed as close as possible to the orifice and in a location where it will not be subjected to an excessive amount of vibration or dust, or to excessively high or low temperatures. For metering steam the recorder should be placed on a level with or below the orifice.

Pipe used to connect the pressure element with the recorder is usually ½-in. iron or brass pipe. The fewer number of fittings used the better, in order to reduce the possibility of leaks. All horizontal sections of the pipes should slope upward toward the orifice in order to prevent air from collecting in pockets.

When the recorders are used to measure steam flow it is necessary that the pipes leading from the orifice be kept filled with water to prevent the steam from coming in contact with the recording mechanism. This necessitates some form of small condenser or reservoirs which will keep the water level at the same height in both the high pressure and the low pressure lines to the recorder.

Steam Served at Any Pressure

Types of Regulating Valves for Delivering Steam at Uniform Reduced Pressure

IN SUPPLYING steam for any definite purpose, it is essential that this steam should be at the proper pressure and temperature to suit the equipment in which it is used. It occasionally occurs that in the same plant are boilers generating steam at different pressures all connected to the same piping system. Sometimes the boiler pressure is too high for the auxiliaries to use the steam directly. Steam furnished for industrial purposes must suit the needs exactly at all times or products are likely to be damaged and financial losses incurred. Then again the heating system must be supplied with steam at a pressure that will not break radiators or cause excessive leaks, that is not at such a high temperature as to be a fire hazard or a source of unreasonable danger to occupants from burns through accidentally touching radiators, pipes or valves.

To suit the needs of the plant for steam at pressures lower than that at which it is generated in the boiler, the steam pressure is reduced by means of a throttling valve, commonly known as a reducing valve or pressure regulator. By this means, not only is the pressure reduced but the steam is also increased in volume and becomes superheated.

In practically all cases where regulating valves are employed, it is essential that the low pressure be maintained constant regardless of changes on the high pressure side of the valve or the demand for low pressure steam. It is also extremely necessary that the pressure in the low pressure piping does not exceed the safe limit due to failure of the valve to function properly.

Many designs of pressure regulators have been developed, all of which may be classified as either weight and lever or spring type, depending upon the means employed for adjusting the valve to give the proper pressure reduction. In each of these classifications are valves using either diaphragms or pistons for actuating the valve discs. Under the spring type are also valves of the pilot type in which the main valve is actuated by steam pressure under the control of the pilot valve.

Valves Regulated by Weight and Lever

In valves of the weight and lever type which employ a diaphragm for actuating the valve stem, such as shown in Fig. 1, there is a balanced steam valve, which may be either single or double seated, the stem of which is attached either directly as in this instance or through levers, in some designs, to diaphragm of rubber composition or, in some cases, metal. One side of the diaphragm is in communication with the low pressure side of the valve the pressure in which tends to force the valve to its seat. This action is partially resisted or balanced by the weighted lever. By varying the position of the weight on the lever, any desired pressure within the range of the valve may be maintained on the low pressure side.

This particular valve is especially designed for use in connection with vacuum or vapor heating systems or other service where close regulation is of importance.

In some designs, the diaphragm is replaced by a piston as is illustrated in Fig. 2. Steam enters the high pressure chamber, passes through the ports into the cylinder, tending to force the piston upward and close the inner valve to which it is attached by a link. This tendency is counteracted by weights suspended from the lever.

Any change in delivery pressure is accompanied by a movement of the lever and a shifting of the position of the valve discs, thus admitting more or less steam in order to maintain the desired pressure. In this par-

ticular design, a dashpot is employed to prevent fluttering valve movement.

Spring Type Regulators

In Fig. 3 is shown a steam pressure regulator of the spring balanced type employing a diaphragm actuated through a water leg by the low pressure steam for maintaining the desired pressure. The heavy spring acting against the diaphragm tends to hold the valve open; this force is opposed by the steam pressure above the diaphragm, the result being that with proper adjustment of the spring tension any desired low pressure may be maintained.

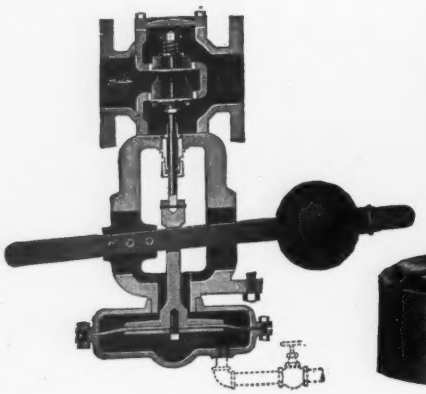


FIG. 1. WEIGHT AND LEVER TYPE VALVE WITH INDEPENDENT DIAPHRAGM

FIG. 2. PISTON OPERATED WEIGHT AND LEVER TYPE VALVE

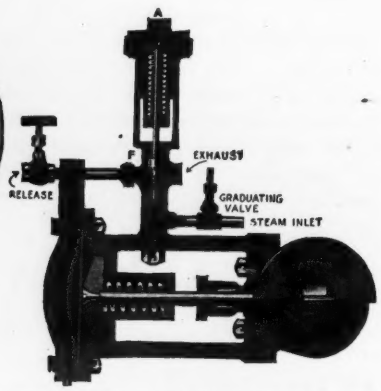


FIG. 5. PILOT VALVE CONTROLS HIGH PRESSURE STEAM TO DIAPHRAGM CHAMBER

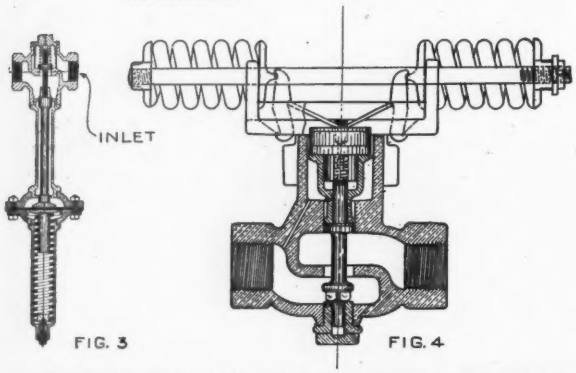


FIG. 3. PRESSURE ON DIAPHRAGM BALANCED BY SPRING TO REGULATE DELIVERY PRESSURE

FIG. 4. PISTON AND COMPENSATING SPRING GIVE CONSTANT DELIVERY PRESSURE

Spring regulated valves may also be made with pistons to vary the opening of the valve with changing demands for steam and pressure, as is illustrated in Fig. 4. In this case, a port leads from the delivery side of the valve to the under side of a spring loaded piston, thus the position of the piston and connected valve stem is such as to secure a balance between the delivery steam pressure and the spring tension which may be adjusted to suit requirements.

Pilot Control

Regulating valves previously described all have direct acting features, that is, variation in delivery pressure actuates the main valve through direct mechanical connection between the diaphragm or piston and the disc. Where it is essential that the high and low pressure be strictly independent of each other, the pilot

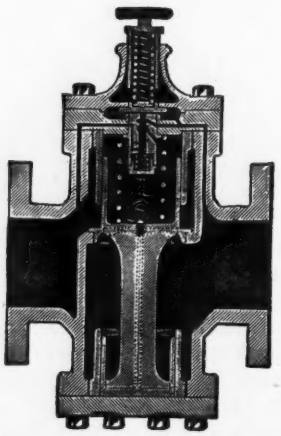


FIG. 6. HIGH PRESSURE STEAM UNDER PILOT VALVE CONTROL OPERATES PISTON TYPE VALVE

valve type of pressure regulators has been found advantageous. Such a valve is shown in Fig. 5, the principles of which are typical of those employing a diaphragm for operating the main valve. In this case, high pressure steam is used against a diaphragm to close the reducing valve. This action is opposed by a spring, the balance of pressure being governed by a pilot valve and resisting plug, the flow of steam from the boiler to the pilot valve being adjusted by a graduating valve. The position of the pilot valve is controlled by a spring loaded diaphragm actuated by variations in pressure in

the low pressure piping and independent of high pressure. Steam passing to graduating valve is allowed to escape freely through the pilot valve in case of increased demand for low pressure steam, but when pressure has reached its upper limit the low pressure diaphragm forces the pilot valve to its seat preventing the exhaust of steam and building up a pressure in the main diaphragm chamber that forces the main valve shut. The action is positive, and sensitive adjustment is possible by means of the adjusting sleeve bearing on the low pressure diaphragm spring.

Pilot controlled valves may also have the main valve actuated by a piston as is illustrated in Fig. 6. In this case, the secondary valve is attached to a diaphragm in the top of the chamber over the piston and a side passage is provided, connecting the chamber under the diaphragm with the outlet. When the spring over the diaphragm is compressed, the diaphragm gives way and thus opens the secondary valve upon which it rests, allowing the steam to escape from the upper side of the main piston valve into the low service, and at the same time opening a port to the under side of the piston, admitting full boiler pressure which lifts the main piston valve open to its full capacity.

Delivery pressure is communicated from the outlet through the side passage and when sufficient to raise the diaphragm and thus close the secondary valve, shutting off high pressure from the bottom of the piston, the high pressure steam fills by the loose fitting piston into the space at the top and forces the valve to its seat.

When installing steam pressure regulating valves, a bypass with a valve should always be provided around them and it is advisable to have a valve on each side of the regulating valve so that it may be removed or repaired without interrupting service to the low pressure system.

To prevent excess pressure on the delivery side, safety demands the use of a relief valve.

Make Your Plant Safe for Attendants

Many Boiler Room Conditions Are Maintained So Close to Danger Point That Safety Provisions Are Absolutely Essential

MAN WAS endowed with five senses to inform him of his surroundings and guide him in his actions. With the exception of taste, all of these are vital to the safe operation of a boiler plant. In cases where our senses cannot reveal directly the condition we wish to know, we resort to instruments. To prevent extreme or dangerous conditions, automatic devices are employed, some of which relieve the condition; others call the attention of the attendant whose duty it is to maintain desirable conditions.

When planning provisions to prevent personal injuries and shutdowns in boiler plants, the first thought is to prevent boiler explosions, and the causes of explosions are sought with the intention of preventing their existence as far as possible.

Over-pressure and low water are the most common causes of boiler explosions. Over-pressure in normal operation is likely to occur with a sudden decrease in demand for steam. A boiler designed for high pressure operation may have deteriorated to such an extent that it is not safe to operate it at more than 70 per cent of its designed pressure. Careful inspection and the hydraulic test are the means adopted for determining the safe pressure, and the steam pressure gage is used to indicate the pressure condition within the boiler.

To relieve the boiler of strains due to over-pressure, safety valves are employed. Power boilers should never have less than two on each boiler. The size of safety valves is limited to 5 in. in diameter and their combined capacity should be sufficient to discharge all the steam that it is possible for the boiler to generate.

Low water results in excessively high temperature of the heating surface above the water level, which not only weakens the tensile strength of the metal but, should water come in contact with it in this heated condition, it is almost certain to crack, due to sudden temperature strains. This low water condition should therefore be guarded against and every precaution taken to prevent it.

Water columns with gage cocks and gage glasses are the essential boiler mountings for determining the water level in the boiler. In addition, however, fusible plugs placed at the minimum allowable water level give warning by melting and allowing the escape of steam that the water level has gone beyond the lower limit and the fire must be drawn.

Some water columns are fitted with alarm features calling attention to undesirable high and low water levels. Gage glasses with reflectors which make the water level more easily seen also decrease the danger of too high or too low water level existing. Personal danger due to the breaking of glass gages is reduced in some plants by employing a device to shield the glass from the face of the attendant who is putting the glass in service. These must be designed so that when not being used they do not obstruct the view of the glass.

Leaking blowoff valves or connections are frequently a source of danger and should be guarded against. The blowoff pipe may be protected from the heat of the furnace by tiling or firebrick housing and careful inspection should be made each time the boiler is down to make sure the piping is not cracked, dangerously corroded or leaking. A check on a leaking blowoff valve is to feel the blowoff piping beyond the valves. In some plants recording thermometers are placed on the blowoff header to detect leaking valves and also give a graphic record of the times of blowing down the boilers.

Two other points on return tubular boilers that give considerable trouble and are sources of danger are the joints between the tube ends and the tube sheets, and the girth seams. What are known as boiler tube thimbles are sometimes used to reinforce the ends of old tubes which have become burned or damaged by rolling. The thimble is driven into the end of the tube so that the flange covers the bead and rolled tightly in place.

Protectors for girth seams of return tubular boilers made of refractory material are sometimes attached to

the rivet heads directly over the fire. The seam is thus shielded from the intense heat which is not readily transmitted through the seam and frequently causes overheating of the rivets and plate, resulting in leaks, crystallization and expansion and contraction strains that weaken the boiler plate.

FIG. 1. BACKGROUND FOR GAGE GLASS WHICH EMPHASIZES WATER LEVEL

When a boiler plate bags and lets go without an explosion or a tube blows out, attendants are subjected to two dangers. One is the blowing of live coals out of the furnace door into the boiler room. This is guarded against in some plants by the use of fire doors that swing inward, or safety latches on the doors. Both

FIG. 2. PROTECTOR FOR GIRTH SEAM MADE OF REFRACTORY MATERIAL

of these provisions are of advantage also in case of a furnace gas explosion.

Probably the more serious danger accompanying a tube blowout is the discharge of steam from the other boilers of the battery back through this boiler and out into the furnace and boiler room. This is guarded against by the provision of a nonreturn valve in the boiler lead which is virtually a steam check valve permitting steam to flow in only one direction through the pipe. The nonreturn valve is also a protection to a man working in one of a battery of boilers while the others are in operation.

Just as over-pressure in boilers is relieved by safety valves, excess pressure in piping, tanks, heaters, economizers or other equipment containing water under pressure is guarded against by the use of relief valves set to discharge when pressure reaches the maximum desirable.

Extreme care in the design and installation of the steam piping in boiler plants must be taken if accidents are to be avoided. Expansion and contraction are sure to accompany the passing of steam through a pipe line, the variation in length depending upon the temperature of the steam. Proper provision must therefore be made to guard against undue strains in all sections of the piping system by the judicious use of expansion bends, joints and pipe anchors.

Water in steam piping is a prolific cause of boiler room accidents due principally to water hammer break-

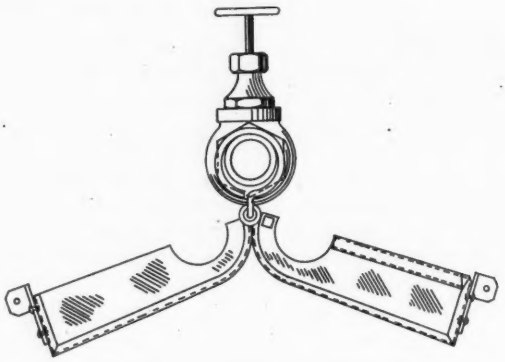


FIG. 3. SAFETY CLAMP TO BE LOCKED OVER VALVE

ing pipe fittings and valves. For this reason, piping should be so graded that condensate will flow in the same direction as the steam and no pockets which are not provided with drains should exist.

To remove the danger of water hammer, the steam piping should be well drained by means of drip piping connected at each low point and upward bend in the piping, also at valves. Where considerable moisture is likely to collect such as at the bottom of a riser, drip pockets may be used to advantage. Safety demands the installation of steam separators in cases where moisture-laden steam is likely to be used in pumps, engines or turbines.

In order that no condensate shall remain in the piping, due to oversight on the part of an attendant, all drip piping should be automatically removed, which may be done either by means of traps or the steam loop system. In either case, for the sake of economy, these high pressure drips should be returned to the feed water heater while hot, thus saving not only the heat but the pure water of condensation as well.

One of the most prolific causes of personal injury is due to falling; to guard against this, the floors should be kept clean and the room well lighted, tools being kept in racks when not actually in use. Iron stairways with

hand rails and grating walkways around the upper parts of the boiler have proved most successful in preventing falls from ladders and undesirable platforms.

Guards around gears and belting are wise precautions and some means for locking valves may in many instances prevent injury or death of a fellow workman.

In the boiler plant where the conditions must be kept so closely within limits, the old adage that "vigilance is the price of safety" applies to its fullest extent. The exertion of every faculty a man possesses is necessary if personal injury and shutdowns are to be avoided.

Safety Devices Are Essential

APPARATUS TO PROMOTE SAFETY IN THE BOILER ROOM SHOULD RECEIVE MOST CAREFUL ATTENTION

SAFETY, FIRST, last, and always, should be a consideration of first importance in the boiler room as in any other well regulated and carefully managed place. Its importance should rank ahead of either

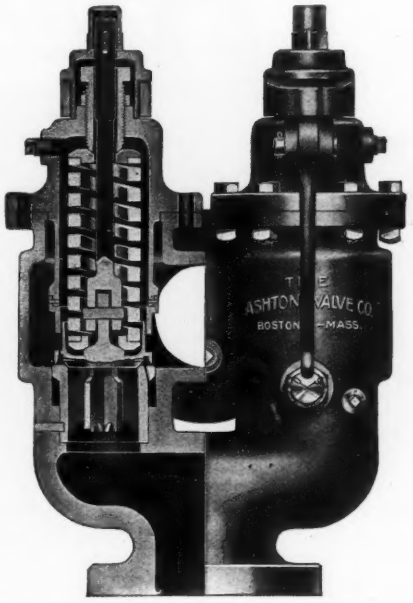


FIG. 1. DOUBLE SPRING LOADED SAFETY VALVE

capacity or efficiency; in reality, the tendency is to underestimate it and were it not for organizations that make it their business to promote safety by recommending certain standards of construction, the toll of unsafe apparatus would be far greater than it is.

In the boiler room the apparatus requiring the most careful attention on this point is the boiler. It is built of certain materials of such dimensions, in such a way as to withstand a given ultimate pressure. This pressure divided by the factor of safety gives the safe allowable working pressure. Any increase in the working pressure above this point is considered unsafe and is not to be tolerated under any circumstances. To prevent such an occurrence, a safety valve is used whose function it is to provide an outlet for the steam to the atmosphere when the pressure has reached the allowable limit.

SAFETY VALVES

SAFETY VALVES are of two general types of construction; the lever and weight loaded, and the spring loaded.

Direct loaded and lever and weight safety valves are not much in favor except on low pressure heating installation. In the case of higher pressures such as are now used in the modern plant this valve becomes too bulky and cumbersome to be useful. The spring loaded so-called pop safety valve is the one almost universally used today, even on the lower pressures. In Figs. 1 and 2 are shown two makes of valve. The principle of operation of all such valves is the same and the construction is practically standard except for minor

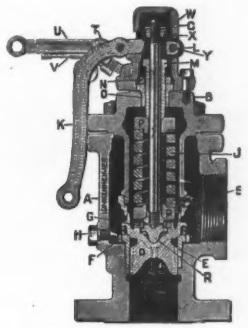


FIG. 2. "POP" SAFETY VALVE WITH BEVEL SEAT AND INCLOSED SPRING

details. The valve disc, which may be either flat or beveled, is held down on top of the seat by means of a coil compression spring. Both valves shown, are provided with 45-deg. bevel seats. The springs of both valves are of the enclosed type, although there are many valves which used the outside spring to keep it out of contact with the steam. The maximum size of valve which may be allowed on a boiler is about 5 in.; if greater relieving capacity is required, two or more units must be employed; they may be mounted separately on individual boiler nozzles, or two valves may be combined in a single body as shown in Fig. 1 and mounted on a single nozzle of the required size.

To prevent the valve from chattering while it is blowing off, the valve disc is made with what is known as a huddling ring. Steam in passing out around the edge of the disc is deflected downward by means of an annular groove beyond the seating face. A reaction is produced which, added to the force due to the pressure in the boiler, keeps the valve open until the boiler pressure has been reduced considerably below the popping point. There are two adjustments that may be made: First, the popping pressure is adjusted by screwing in or out on the nut controlling the spring tension; second, the amount of blow down, i.e., the reduction in pressure that takes place before the valve can close, is

determined by adjusting the position of the huddling ring.

Safety valves should be attached directly to the boiler nozzle without valves of any description between it and the boiler. If it is desired to use an exhaust pipe instead of allowing the steam to blow into the boiler room, this pipe should run direct to the roof and should contain no fittings or valves and it should also be drained at its lowest point.

Non-Return Valves

To prevent steam from other boilers in a battery from blowing back into a boiler in which the pressure has been reduced, due to a tube failure, for instance, non-return valves are used such as are illustrated in Figs. 3, 4 and 5. Such a valve is also a safeguard for anyone working in one of a battery of boilers. As there is atmospheric pressure under the valve, the disc is held tight on its seat by the header pressure, and there is no danger of steam getting into the boiler. In principle the non-return valve is a combination globe and check valve. By turning down the handle the valve may be closed, but turning out does not open the valve; instead it simply allows it to be opened if the pressure conditions are right, i. e., if the pressure under the disc exceeds that above it. As long as the boiler pressure exceeds the header pressure, the valve will remain open and flow will be maintained. As soon, however, as the boiler pressure drops below that in the header, there will be a tendency for reversal of flow and this tendency increasing the pressure above the valve disc will force it down on its seat and prevent this reversal at its inception.

Slamming of the valve is prevented by means of a dash pot as shown in Fig. 3 or by a counterweight as shown in Fig. 4, or by a combination of the two as in Fig. 5. The valve illustrated in Fig. 4 is provided with two discs and seats working in opposite directions. Besides checking any tendency toward reversal of flow, this valve also closes in the event of a sudden increase above normal of the flow from the boiler.

Automatic Removal of Water of Condensation

Steam piping in the power plant is designed for the sole purpose of conveying steam from the generating to the consuming units. Water has no place in such a system. It is, however, bound to form, and must therefore be disposed of. The presence of water in steam lines is due to two causes. It is carried into the line from the boiler because of priming or foaming in the boiler, or it is formed by condensation of steam in the piping due to insufficient insulation. The amount carried may be reduced by providing ample disengaging surface in the boiler, to reduce priming, by using properly treated water to reduce foaming, by using an efficient dry pipe in the boiler, by using superheated steam and by providing first class pipe covering.

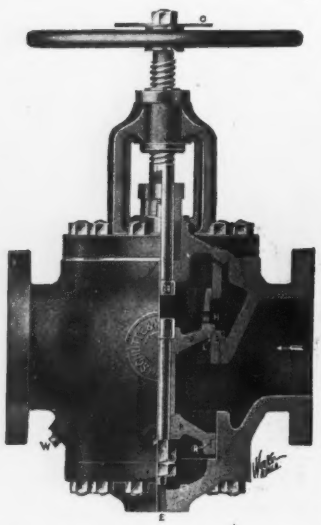


FIG. 3. NON-RETURN VALVE PROVIDED WITH DASH POT

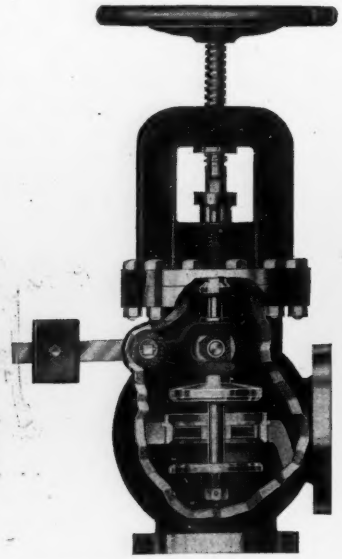


FIG. 4. DOUBLE-SEATED NON-RETURN VALVE

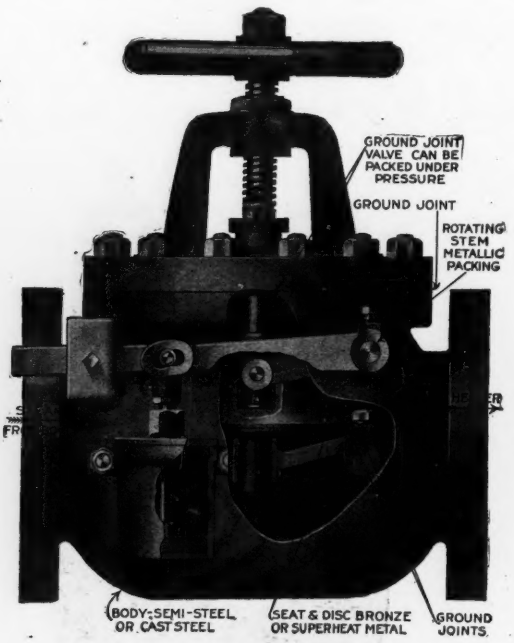

GROUND JOINT VALVE CAN BE PACKED UNDER PRESSURE
GROUND JOINT
ROTATING STEM METALLIC PACKING
BODY: SEMI-STEEL OR CAST STEEL
SEAT & DISC BRONZE OR SUPERHEAT METAL
GROUND JOINTS

FIG. 5. NON-RETURN VALVE WITH COUNTER WEIGHT AND DASH POT

Water in the steam, especially where it has accumulated into slugs, is extremely dangerous. Such a slug carried along with the steam at a velocity of from 6000 to 10,000 ft. per min, is likely to shatter any elbow which it strikes. It is also dangerous either to reciprocating engines or turbines, being likely to cause a blowing out of the cylinder head in one case or to rupture the blading in the other.

To reduce the likelihood of the formation of slugs all piping should be definitely pitched in the direction in which the steam is to flow, pockets should be carefully avoided, and risers should be provided with drips at the base. When piping is pitched the wrong way the flow of condensate along the bottom of the pipe will be in a direction opposite to that of the steam. As a consequence it will pile up until a sufficient quantity has accumulated almost to block the passage, when it will be picked up by the steam and carried along bodily. Wherever pockets are permitted to exist, condensate will accumulate until it offers too great an

obstacle to the flow of steam, when it will pick up as before. Condensation in a riser will of course fall to the bottom, where it will accumulate until the action just described occurs.

It is essential, then, in the interests of safety, that condensation or other water in the steam line be removed from the path of the steam flow as fast as it accumulates. For this reason, all points in the piping system susceptible to such accumulation should be provided with drips. A drip is simply a piece of small diameter piping screwed into the under side of the steam line in such a way that the end of the drip line is flush with or below the inside surface of the main pipe. Water running along the bottom of the pipe will drain into the drip line whence it flows by gravity to a receiver.

To prevent slugs of water getting to engines and turbines, large capacity receiver separators are placed in

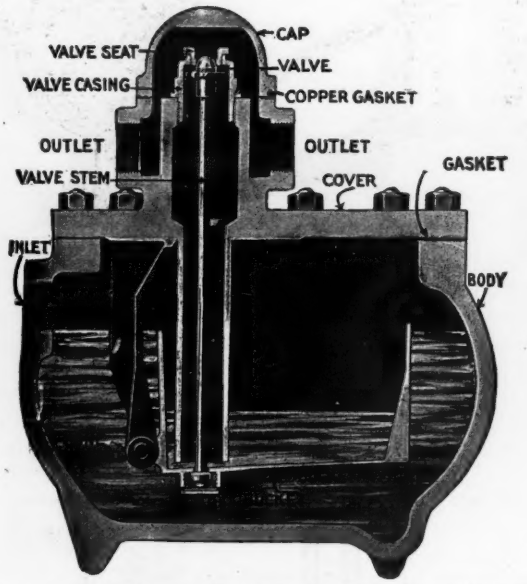


FIG. 6. BUCKET TYPE STEAM TRAP WITH TOP DISCHARGE

the line immediately adjacent to the throttle valve. In this separator the steam flow suffers a sudden reversal, the entrained water having a greater momentum due to its weight is unable thus to reverse its flow and instead falls inert into the separator, from which it may be drained by such a drip pipe as mentioned.

To insure efficient functioning of these drips it is necessary that the receiver be blown out regularly so that condensate will not back up into the steam line. To obviate the necessity of the always unreliable manual control this receiver may be made a part of what is known as a Holly steam loop by means of which the hot condensate is automatically returned to the boiler. In this system a closed tank is placed above the boiler and connected to the steam system by two pipes. One admitting into the upper portion is connected to the under side of the receiver; the other from the bottom tank connects into the boiler. Connected to the top of the tank is a vent. If this vent is opened, the pressure in the tank will be lowered and water will rise in the pipe connecting to the boiler, to such a height that the added head counterbalances the difference in pressure between the boiler and tank and steam will flow through the other pipe to equalize the pressure. If this steam carries water in suspension it will be swept along and discharged into the tank, thus increasing the head of water in the return line and water will flow back to the boiler until conditions have been equalized. This action causes slugs of water and steam to rise from the receiver to the discharge tank.

Steam Traps

Another method of handling the condensate from the drip lines is by means of a steam trap. This apparatus is connected directly to the drain line and discharges the condensate as it accumulated directly to

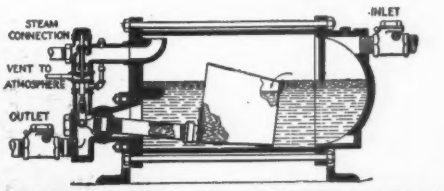


FIG. 7. VENTED BUCKET TRAP WITH BOTTOM DISCHARGE

the hot well or feed water heater. The water is hot as it is discharged and all the sensible heat is returned to the boiler. They are of several general types, as explained in a previous section—bucket, float, tilting, piston operated and expansion. They are all applicable in a general way to the same class of work; nevertheless there are certain types that are better suited for some particular service than others.

In the first category may be included such traps as shown in Figs. 6 and 7. In the trap shown in Fig. 6 condensation enters at the left and is deflected by a baffle plate toward the bottom, where sediment may collect and be blown off through the clean out. Water rising in the body of the trap forces the bucket upward and closes the discharge valve at the top. It remains in this position until the water has risen in the body to the rim of the bucket and enough has spilled in to overbalance it and cause it to sink to its original position. This action opens the discharge valve and steam pressure within forces the water in the bucket up through the drop sleeve and out through the valve.

In Fig. 7 is shown another type of bucket trap. As the trap fills, through the inlet on the right, the vent shown on the left hand side is opened to atmosphere, thus relieving the pressure within the trap and allowing for more rapid filling. The bucket rises until it is stopped by coming in contact with the top of the body. The condensate level continues to rise until it overflows into the bucket which subsequently begins to sink. As it does so the valve spindle rises, closing the vent to atmosphere and admitting full steam pressure above the condensate level. At the same time the trunnion valve is opened and the water is discharged from the bucket through the connecting pipe. On account of the use of the vent mentioned it is unnecessary to place this trap below the system to be drained. With the vent open there is a reduction in pressure in the trap and the condensate collected in the low point of the drainage system is forced up into the trap by the steam pressure behind it.

Another type of bucket trap such as shown in Fig. 8 employs a somewhat different principle of operation. In this type the bucket is upside down and the type

is referred to as the inverted bucket trap. In the particular trap illustrated the bucket hangs open end down directly over the inlet which is centrally located in the bottom of the body. As the outlet is at the top the trap must be full of water before discharge can take place. Water entering the trap flows into the open end of the bucket and then out and around the bottom, up and through the valve, this action continuing as long as water enters. As the system is drained of water, steam enters the bucket, displacing some of the water there. As it does so, the buoyancy of the bucket increases until it rises and closes the discharge valve through a system of compound leverage. As this is taking place, the steam in the basket condenses and unless more steam enters to take its place the bucket drops and opens the valve. Thus, as long as water is coming to the trap, the discharge is open; as soon as steam appears, it closes. The purpose of the small vent in the top of the bucket is to relieve non-condensible gases. Such gas accumulates under the valve and is discharged with the condensate.

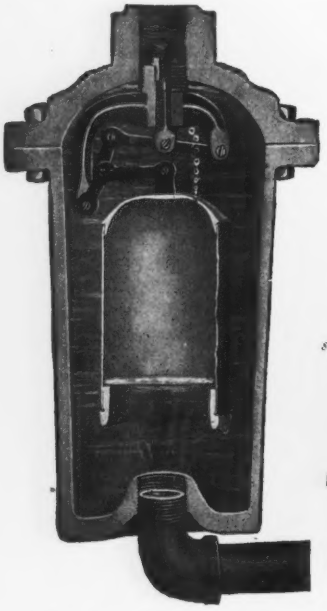


FIG. 8. INVERTED BUCKET TYPE TRAP

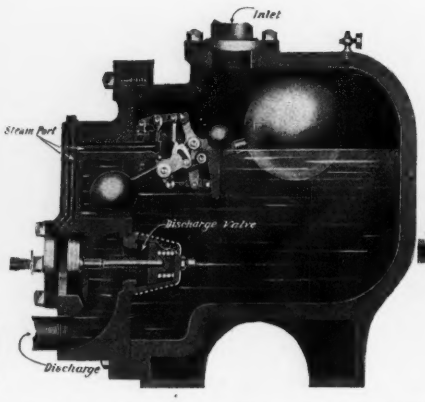


FIG. 9. FLOAT TRAP WITH PISTON OPERATED DISCHARGE VALVE

In Fig. 9 is illustrated a float type trap, the discharge valve of which is operated by a steam piston. As water of condensation accumulates in the body of the trap through the inlet at the top, it raises the float until a point is reached where it trips a counterweight which in falling opens a pilot valve and admits steam pressure behind the valve piston, thus opening the discharge line. As the water is discharged, the float drops and in so doing closes the pilot valve and allows the main valve to close. This action takes place before the water level has lowered to the level of the discharge opening, thereby maintaining a water seal at this point.

Tilting type traps may be illustrated by one such as shown in Fig. 10. In this trap water enters through the hollow trunnion and rises in the bowl until its weight overbalances the counterpoise above and it drops to the bottom of the guide. As this bowl falls, an extension arm on the opposite side of the trunnion engages the stem of the valve shown and opens it, admitting steam through the other trunnion support and through a connecting pipe to a space above the water in the bowl, thus forcing it out through the discharge line. Water enters and leaves the trap through the same trunnion, the direction of flow being controlled by two check valves, one in the inlet and the other in the discharge line.

What is known as a differential trap is shown in section in Fig. 11. Referring to the illustration, water of condensation entering at A is directed to the lower chamber, Y, through the annular space between the two tubes shown, until this space is completely filled. At this point the pressure under the diaphragm, F, is greater than that above by an amount due to the full head or in the annular space and it presses upward on the valve, V, forcing it closed. As more water enters at A, it accumulates above the diaphragm until the head

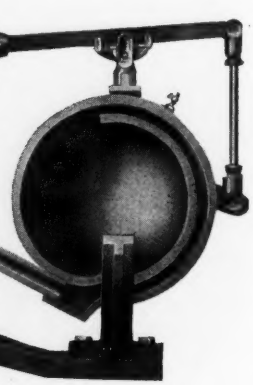


FIG. 10. TILTING TYPE STEAM TRAP

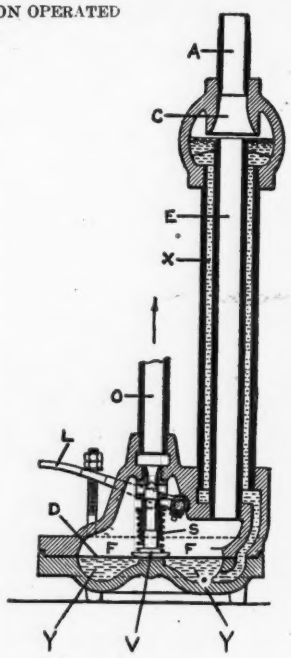


FIG. 11. DIFFERENTIAL, DIAPHRAGM, STEAM TRAP

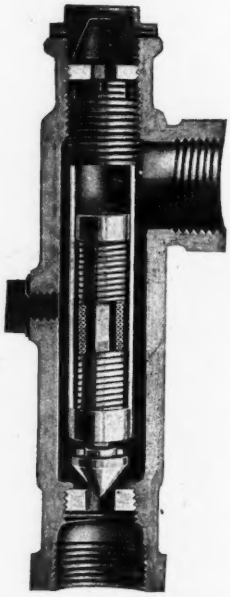


FIG. 12. EXPANSION TRAP USING OIL EXPANSION AS THE MOTIVE POWER

produced in combination with the spring, S, is sufficient to relieve the unbalanced pressure on the diaphragm and allow the valve to open, allowing the water above the diaphragm and in the inner tube to be discharged. As discharge takes place, the head in the inner tube is reduced and the valve closes.

Expansion traps may be classed in accordance with the material used for the expansion member. There are traps that make use of the expansion of one or, in some cases, two different metals to actuate the valve in the discharge line. Another type uses the expansion of a volatile fluid confined in Bourdon tube arrangement or in a flat hollow disc to control the opening and closing of the discharge valve. Yet another type makes use of liquid expansion in spirally corrugated tube which is attached direct to the valve disc so that the elongation and contraction of the tube under varying temperatures imposed by contact with first water and then steam, opens and closes the discharge valve. These types have been used mainly for low pressure service principally on heating systems. The last mentioned type has, however, been applied to high pressure work. Such a trap is shown in section in Fig. 12. It consists of a small body into which the inlet and discharge connections are made; the inlet at the side near the top and the discharge at the bottom. In this body a cartridge containing a heavy hydro-carbon oil having a high coefficient of expansion, is inserted. This oil operates a corrugated, hermetically sealed, brass tube, to the lower end of which is attached a piston which carries the valve head. While there is water in the body of the trap the oil is cool and in a contracted state and the valve head is lifted from its seat, permitting the water to be discharged. Steam in the trap expands the oil and forces the valve onto its seat, thus preventing the steam from flowing through. This trap is small and compact and can be installed as part of the piping without additional support. Due to its construction, it has but little reserve capacity, hence where sudden large slugs of water must be disposed of quickly a trap of the receiver type having a large storage capacity is to be preferred.

Safety Involved in Use of Pressure Gages

PROPER LOCATION, WELL ARRANGED CONNECTION SCHEME AND FREQUENT TESTING OF GAGES NECESSARY FOR SAFE OPERATING CONDITIONS

AS A PART of the high pressure piping system, gages, their use, installation and care are of importance from the standpoint of safety as well as the operating viewpoint. Although progress has been made in gage manufacture until these instruments are quite rugged and extremely reliable, nevertheless there are certain points which must be considered which add to their accuracy and therefore to the over-all safety of the plant.

In its report, the Boiler Code Committee of the A. S. M. E. has this to say regarding steam pressure gages: "Each boiler shall have a steam gage connected to the steam space or to the water column or its steam connection. The steam gage shall be connected to a siphon or equivalent device of sufficient capacity to keep the gage tube filled with water and so arranged that the gage cannot be shut off from the boiler except by a cock placed near the gage and provided with a tee or lever handle arranged to be parallel to the pipe in which it is located when the cock is open. Connections to gages shall be of brass, copper or bronze composition.

"Where the use of a long pipe is necessary, an exception may be made to the rule that the gage must be arranged so that it cannot be shut off except by a cock placed near the gage and a shutoff valve or cock arranged so that it can be locked or sealed open may be used near the boiler. Such a pipe shall be of ample size and arranged so that it may be cleared by blowing out. The dial of the steam gage shall be graduated to not less than one and one-half times the maximum allowable working pressure on the boiler. Each boiler shall be provided with a ¼-in. pipe valved connection for the exclusive purpose of attaching a test gage when the boiler is in service, so that the accuracy of the boiler steam gage can be ascertained."

One method of making the gage connections and which conforms to the recommendations just cited is that shown in Fig. 1. In this scheme, as is frequently the case, provision has been made at the top of the water column for the gage connection. The cross A is used and a valve B is placed in the gage line. At C is the

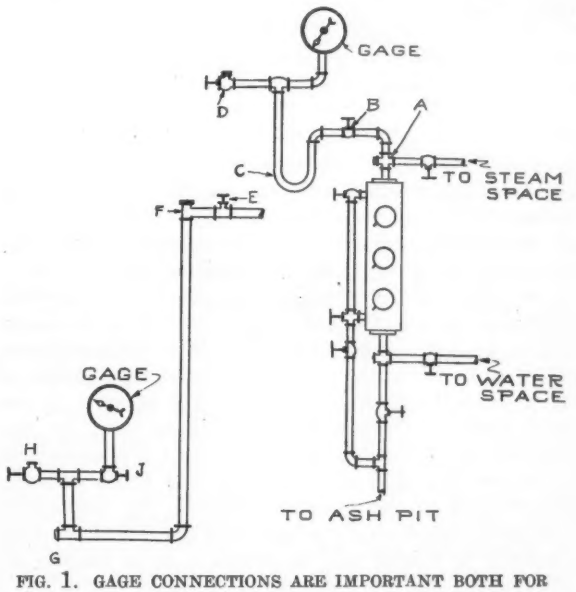


FIG. 1. GAGE CONNECTIONS ARE IMPORTANT BOTH FOR ACCURACY AND SAFETY

section of the piping that provides the water seal and prevents the steam from coming in contact with the gage mechanism. Arrangement for a test connection is made by placing an angle valve at D.

Quite frequently it is desired to place a high pressure steam gage on a central board located on the boiler room floor. This is permissible if done in accordance with the rules given by the A. S. M. E. Code.

One such scheme is shown in the left-hand part of Fig. 1. In this case, the valve E must be locked in the

open position and it is also necessary to make provision for blowing out the pipe line. The valve J can be closed, valve E closed and plug G removed, which allows the water to drain out. Valve E may then be opened and the line blown out. The line may then be filled with water at F. As there is little danger of the connecting pipe clogging up it is not customary to blow out such lines except at long intervals.

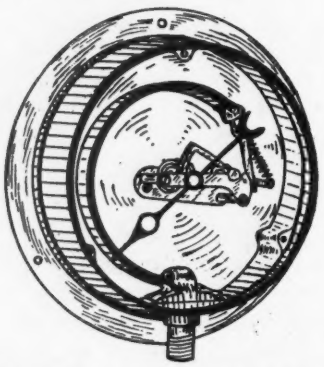


FIG. 2. MECHANISM OF A TYPICAL BOURDON PRESSURE GAGE

It will be noted that the water seal extends up to F and is maintained at that level by condensate. As this adds a head to the gage reading, proper account must be taken of this in the calibration of gages so located. This can be done by setting the gage at zero with the valve E closed.

Even where a gage is used on a panel on the boiler room floor, it is also considered good practice to have a gage at the water column.

Types of Gages

For purpose of indicating pressures, three general types of gages are employed, the Bourdon type, the diaphragm type and the manometer or U tube. Gages of the Bourdon and diaphragm types consist of two essential parts, the pressure element and the movement.

In gages of the Bourdon type, pressure is applied internally to an elastic hollow brass or steel tube of oval section, bent into the shape of a circular arc and closed at one end. Since the closed end of the tube is free to move, while the other end is fixed, fluid pressure on the inside tends to increase the short diameter of the section, causing the radius of curvature of the whole tube to become larger, thus moving the free end a distance proportional to the pressure applied. By connecting a suitable multiplying mechanism to the end of the tube a spindle or pointer may be moved so as to indicate on a graduated dial the pressure in the units desired.

Generally the multiplying mechanism is made up of one or more levers, a toothed segment or sector, a pinion and a hair spring. Adjustment of the ratio of movement between the pointer and the end of the tube is made by either a slotted sector rim or a connecting link, the length of which may readily be changed to suit conditions. Lost motion of the parts is taken up by the hair spring attached to the spindle carrying the pointer.

Owing to pointer vibration due to jarring which occurs in certain classes of service, also the rapid fluctuations of pressure sometimes encountered, double-spring gages are frequently employed. The pressure tubes in such a gage may consist of two separate branches or may be continuous; but in either case, there are two free ends, which, when properly connected by a lever mechanism, give a greater pointer movement than is obtained with a single spring.

In the diaphragm gage, the indicating device is actuated by a corrugated metal disk or diaphragm, clamped around its edges by the flame of an encircling chamber. The deflection of the diaphragm is proportional to the pressure applied to its lower side, and its movement is communicated to the pointer by a mechanism similar to that used in the Bourdon type.

Bourdon gages can be used for indicating pressures of liquids, steam or gases, where the tube does not reach a temperature much in excess of 150 deg. F., as above this limit the temper of the tube is likely to be affected. When used for steam pressures, therefore, a siphon must always be employed to prevent steam coming into contact with the tube, and should be of sufficient capacity to fill the gage tube with water.

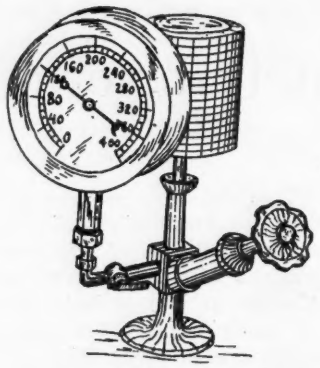


FIG. 3. GAGES ARE USUALLY CALIBRATED BY MEANS OF A DEAD WEIGHT TESTER

Calibrating Pressure Gages

Gages may be checked for accuracy and calibrated by means either of comparison with a standard gage or the use of a dead-weight testing device, such as shown in Fig. 3. This tester consists of a stand from which rises a cylinder, having accurately fitted into it a piston with an area of 1.5 sq. in. which moves freely up and down. Attached to the top of the rod is a disk for the support of the weights; each weight is marked with the number of pounds pressure per square inch that it will exert on the gage. From the bottom of the cylinder, two tubes project; one from a standard for holding the gage to be tested while the other, inclined, serves as a reservoir for oil and is fitted with a screw plunger.

After the gage under test is attached and the three-way cock placed horizontally, the reservoir is filled with oil. This is done by turning the plunger inward to the extreme of its travel and pouring oil into the cylinder until filled; the plunger is then gradually withdrawn and at the same time more oil is added, continuing this until the plunger is in its outer position and with the cylinder nearly full.

With the cock under the gage open, the piston is inserted, which with its disk will indicate a pressure of about 5 lb. on the gage. The weights, one at a time,

may now be placed on the disk which should be gently rotated to insure perfect freedom of motion to the piston. Each weight added will indicate a pressure on the gage equal to the number of pounds marked on it, and if the reading of the gage does not correspond to the total number of weights added, corrections of readings will have to be made for the error.

If, in testing a large gage, the piston descends to its full length screwing in the plunger will force it upward, thus allowing the addition of more weight as may be required.

Records Stimulate Economy

Operating Standards Established Form the Foundation for Higher Efficiency

BEST RESULTS can be obtained in any boiler room if the attendants perform their work along a definite routine; the various duties then become a matter of habit, and the work can be accomplished much more quickly and satisfactorily than if no routine were followed and each individual did the work that seemed most pressing at the moment.

One of the most important duties of the foreman is, therefore, to work out a program for each man employed in the boiler room assigning certain duties to be done at specified times throughout the day. All other assignments should be considered secondary to the routine work. Not only should this schedule be followed to the letter but a record should be kept on the log sheet stating definitely the time each important routine duty was performed.

To plan such a program, each piece of equipment or device in the boiler room must be considered. It is well to draw up rules for starting, stopping and operating individual units and with these instructions as a guide a working schedule can be planned so as to give proper attention to all equipment in the plant.

In addition to the manual work, it is extremely important to have a record on the log sheet of instrument readings, giving not only quantities of material dealt with but physical or chemical conditions which exist at various times during the day.

Recording instruments have many advantages over the indicating type, but should not replace them entirely. Even though the plant is equipped with recording instruments, attendants should be required to take frequent readings of the most important instruments and make note of them on the log sheet so that there can be no question that they know the conditions under which the equipment is operating.

Regarding boiler operation the following items should have a place on the log sheet of a plant equipped with all the necessary instruments to give the necessary data. Steam pressure and temperature should remain constant but some variation is inevitable and as the changes may take place quite rapidly the readings should be recorded hourly at least. Feed water temperature is another variable item which should be frequently noted and recorded hourly.

Each time the safety valve blows the time and duration should be made an item of record. This is a direct loss due to over-pressure which might be avoided in most instances. The amount of water fed to the boiler and the steam delivered during each hour are valuable items for comparison. One should check the other or, if not, the difference represents loss through safety valve, blowoff valve or leaks.

Although it is claimed in some plants that the blowoff valve is never opened except when cleaning the boiler, the usual and recommended practice is to blow down at least once a day or once a watch in most cases. The same frequence of blowing down the water column is recognized as good practice and it is well to include both of these items and the amount of blowdown in the log sheet.

Time the boiler is in actual operation, banked or fires out has a bearing on the economy of the plant and should be carefully noted on the log.

Two other items which are usually matters of routine are the dusting of the tubes and the testing of the boiler water, which are done in most plants once each watch.

In the operation of the furnace, the items of principal importance are the amount of coal burned per hour, the CO_2 in the gases, flue gas temperature, and the furnace and differential draft. Each of these should be recorded hourly. To this list might well be added depth of fuel bed, ash made per hour, stoker speed, air temperature and barometric pressure. The kind of coal should be noted on each daily log and at time of changing quality.

Items of value in the operation of feed water heaters are the amount of water heated per hour, temperature of the water at inlet and outlet, exhaust steam pressure and temperature escape of exhaust steam to atmosphere, all of which should be recorded hourly.

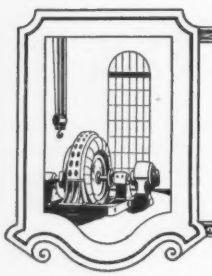
Records kept of other auxiliaries are principally the times of starting and stopping.

All valves or other manually operated devices should be worked occasionally, at least once a day or as frequently as possible, to make certain that they are in working order.

Automatic devices must be kept in condition to function properly and each of these should be given a tryout once a day at least, if not in continuous operation, or at a time when the tryout will not interfere with operation. These tests should be reported on the log sheet as a matter of record.

Instruments especially need careful watching to make sure they are reasonably accurate. A regular routine of inspection and calibration should be established to prevent errors. Each day the log sheet and instrument records should be gathered up and compared with a standard which has been worked out to give best results in that particular power plant. Any variation from this standard indicates conditions which invite investigation. If below standard, some condition needs correction; if above, a determination of the cause may lead to a change in practice which will result in greater economy.

Merely keeping records has little value; to be of real benefit, the data collected must be totaled, averaged, compared with previous results and when causes of discrepancies have been determined steps should be taken immediately to correct the faults. It is the immediate showing up of poor results and prompt remedy that make record keeping profitable to the plant.



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Instrument Transformers for Power Circuits---I

General Considerations Regarding the Theory of Voltage Transformers. By J. B. Gibbs*

MODERN POWER systems use high voltages and large currents. It would be impossible to measure these quantities directly, because instruments insulated for present day transmission voltages and adapted for the corresponding currents, are impracticable. Such voltages at the switchboard would also be extremely dangerous to attendants. For these reasons, instrument transformers are used.

FIG. 1. VOLTAGE TRANSFORMER, 2300-V. CLASS

It is the function of the instrument transformer to deliver to the instruments and control circuits a miniature reproduction of the voltage and current in the power circuit. The miniature voltage must always be accurately proportional to the voltage in the power circuit and the miniature current must be accurately proportional to the current in the power circuit. Since wattmeters are usually included among the measuring instruments, it is also necessary that the miniature voltage and current correspond closely in phase with the voltage and current in the power circuit.

Since the insulation of the instrument transformers protects the instruments and also the attendants from the high voltage of the power system, it is important that it be of the best quality, ample in quantity and properly placed. Instrument transformers for the lower voltages are often made for operation without oil, but transformers for higher voltages are oil immersed. Oil is an excellent insulating and cooling medium and helps to keep the transformer free from the moisture in the atmosphere.

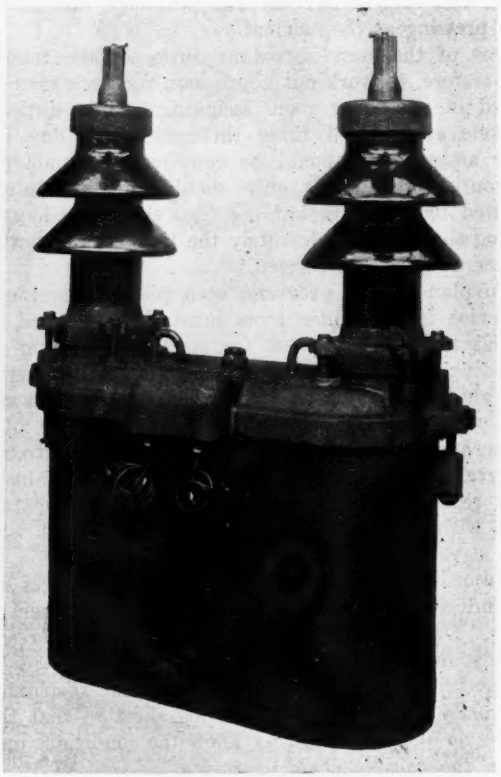


FIG. 2. VOLTAGE TRANSFORMER, 22,000-V. CLASS

For certain uses of instrument transformers, it is necessary to know the relative direction of the current in the primary and secondary windings. For this reason, the "polarity" of instrument transformers is marked. Some form of marker is put on, or adjacent to, one of the primary leads and one of the secondary leads. The markers are placed so that when current is flowing

* Transformer Engineer, Westinghouse Electric & Mfg. Co.

toward the transformer in the marked primary lead, current will be flowing away from the transformer in the marked secondary lead. Knowing this convention, it is easy to make allowance for the effect of the transformer when connecting instruments or relays.

Instrument transformers operate on the same general principle as all transformers. A current flowing in the primary winding causes a magnetic flux in the iron core. This flux in turn induces a voltage in the secondary coil, thus causing a current to flow if the secondary circuit

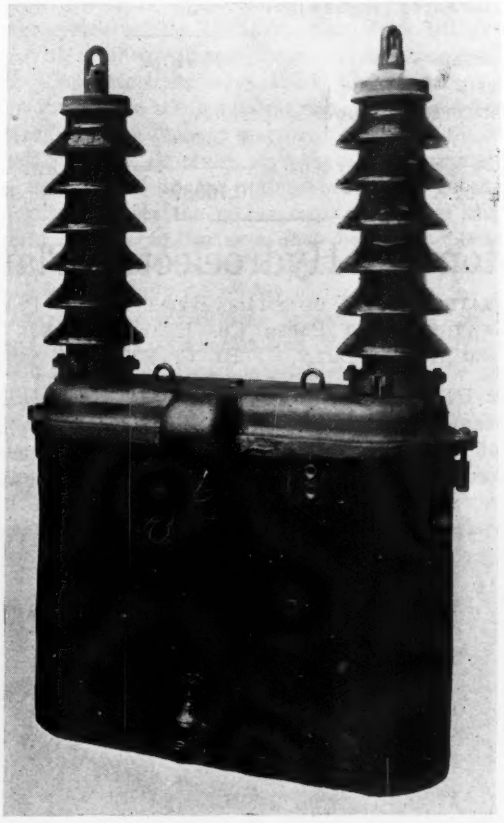


FIG. 3. OUTDOOR VOLTAGE TRANSFORMER, 66,000-V. CLASS

is closed. The details of construction of instrument transformers are different than those of power transformers, because of the different purpose for which they are used.

VOLTAGE TRANSFORMERS

VOLTAGE TRANSFORMERS are made in a large variety of sizes and types. They generally have a small rating, usually 200 volt-amperes, because the only secondary load which they are intended to carry is a few instruments or relays. Figures 1, 2 and 3 show typical voltage transformers for various line voltages.

An ideal voltage transformer would have zero regulation, that is its secondary voltage would not change as its load changed. The secondary voltage would bear the rated ratio to the primary voltage; and the secondary voltage would always be exactly 180 deg. behind the primary voltage. These conditions are impossible of exact fulfillment, and the process of voltage transformer design consists in making the best possible approximation to the ideal, considering both cost and performance.

Regulation is made low by keeping the losses and the reactance low. The secondary voltage is then "compensated" for the particular load to be carried. This is done by leaving off a certain number of the primary turns. The actual ratio of the transformer is thus changed just enough to make up for the voltage drop at the given load. The small losses in the transformer insure a small phase angle.

Voltage transformers are used with voltmeters, wattmeters, watthour meters, power factor meters, frequency

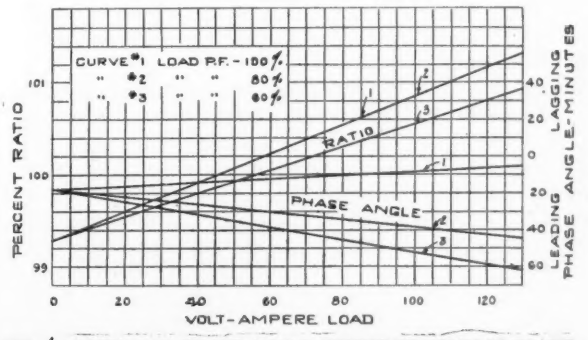


FIG. 4. RATIO AND PHASE ANGLE CURVES OF VOLTAGE TRANSFORMERS. RATIO 2300 TO 115 V., 60 CYCLES

meters, synchronoscopes and synchronizing apparatus, relays and automatic circuit breaker trip coils. A single voltage transformer can be used for a number of instruments, if the total load does not exceed that for which the transformer is designed and compensated. With instruments which have voltage coils only, such as voltmeters, frequency meters and some relays, no attention need be paid to the polarity of the voltage transformer, nor to its phase angle; but polarity and phase angle must be carefully considered when voltage transformers are

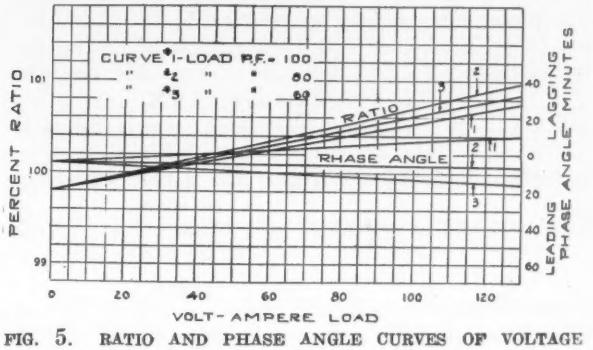


FIG. 5. RATIO AND PHASE ANGLE CURVES OF VOLTAGE TRANSFORMER. RATIO 6900 TO 115 V., 60 CYCLES

used with wattmeters, watthour meters, power factor meters or any device which depends on the mutual action of two independent coils.

Figures 4 and 5 are typical ratio and phase angle curves of voltage transformers. The "per cent ratio" is the factor by which the secondary voltage of the transformer must be multiplied to correct for the ratio error of the transformer.

Example: A voltmeter on the secondary of the 2300-v. voltage transformer reads 108 v. What is the voltage of the primary circuit corrected for the transformer error. The total load on the secondary of the

voltage transformer is 60 v. amp. at 80 per cent power factor.

Solution: From the curve, Fig. 4, the per cent ratio when the load is 60 v. amp. and the power factor is 80 per cent, is 100.23 per cent.

$$108 \times 20 \times 100.23 \text{ per cent} = 2165 \text{ v.}$$

The load and power factor here referred to are, of course, the load and power factor on the secondary of the voltage transformer. The phase angle is the angle between the voltage delivered by the secondary of the voltage transformer and the reversed primary voltage. This may be either lagging or leading, depending on the characteristics of the transformer and the power factor of the secondary load.

The phase angle of a voltage transformer has no effect on the reading of a voltmeter. Its effect on the reading of the wattmeter depends on the power factor of the main power circuit as well as on the characteristics of the voltage transformer. This is most easily seen by means of a vector diagram. In Fig. 6 OE represents the

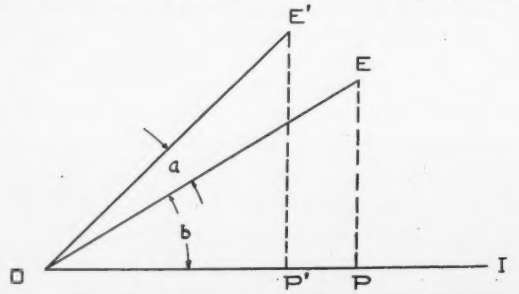


FIG. 6. VECTOR DIAGRAM OF VOLTAGE AND CURRENT IN ALTERNATING CURRENT CIRCUIT

voltage and OI the current in a circuit which is to be metered. The true power is measured by OI $\times$ OP = OI $\times$ OE cos a. Now suppose that a voltage transformer is used which delivers the voltage OE′ instead of OE. The power measured by wattmeter will be OI $\times$ OE′ cos (a + b), when b is the phase angle of the voltage transformer. To find the true power, this must be multiplied by $\frac{OE}{OE'} \times \frac{\cos a}{\cos (a+b)}$. $\frac{OE}{OE'}$ is the ratio correction factor, k′, therefore the actual wattmeter reading should be multiplied by $k' \frac{\cos a}{\cos (a+b)}$. True watts = wattmeter reading $\times k' \frac{\cos a}{\cos (a+b)}$. In this formula, b is positive when the secondary voltage of the voltage transformer leads the primary as shown in Fig. 6.

Example: A voltage transformer having the characteristics shown in Fig. 4 is used with a wattmeter in the measurement of power. The instrument load on the voltage transformer amounts to 75 v. amp. at 80 per cent power factor. The wattmeter reads 525 kw., the voltmeter reads 2300, and the current is 300 amp. What is the power, corrected for the voltage transformer errors?

Solution: The ratio of the transformer at 75 v.-amp. load 80 per cent power factor is (from ratio curve No. 2, Fig. 4) 100.47 per cent. Therefore, the corrected voltage is

$$2300 \times 100.47 \text{ per cent} = 2311 \text{ v.}$$

Since both the reading of volts and the reading of watts are taken on the secondary of the voltage transformer, we are dealing with the quantities OI on OE′ (Fig. 6). The apparent power factor calculated from the meter readings is really cos (a + b), therefore, instead of cos a

$$\cos (a+b) = \frac{525 \times 1000}{2300 \times 300} = 0.76087$$

$$a + b = 40^\circ\ 27'\ 32''$$

From the curve (Fig. 4) $b = \quad 33'$

subtracting, $= a \quad 39^\circ\ 54'\ 32''$

and cos a = 0.76688.

The corrected power is therefore,

$$525 \times 100.47 \text{ per cent} \times \frac{0.76688}{0.76087} = 531.62 \text{ kw.}$$

Automatic Hydroelectric Plant

AUTOMATIC CONTROL OF SMALL HYDROELECTRIC PLANT AT NEWTON FALLS PAPER CO. ENABLES WATER TO BE USED ECONOMICALLY. BY C. E. VON SOTHEN*

AN INTERESTING example of the economy that can be obtained in plant operation by the application of automatically controlled generating equipment is afforded by such an equipment that recently went

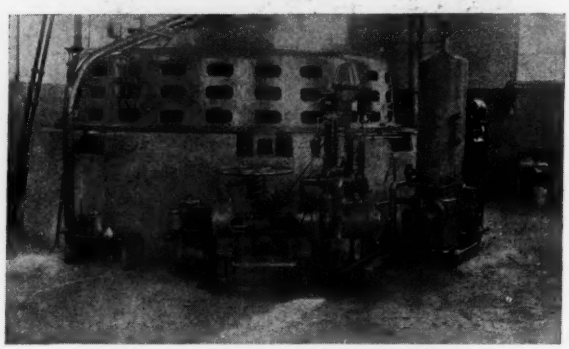


FIG. 1. GENERATOR WITH OIL PRESSURE GOVERNOR, ACCUMULATOR AND MOTOR DRIVEN COMPRESSOR FOR OPERATING THE GATES

into operation at the mill of the Newton Falls Paper Co. This mill is supplied with power from the 22,000-v. lines of the Northern New York Utilities Co. The power contract calls for about 1000 hp., on a 5-min. peak basis, with no charge for momentary peaks. The operation of super-calenders in the mill causing considerable variation in the load demand, the company installed, in 1917, a manually controlled, 850 kv.a., 2300-v., water-wheel driven generator on a small power site with approximately 25 ft. head that existed about 4000 ft. from the mill. The purpose of the station was to take care of the peaks caused by the super-calenders, and thus flatten out the load curve on the central station lines, with a consequent reduction in the power bill. Since the station runs 24 hr. a day, and the presence of

* Engineer, Power and Mining Dept., General Electric Co.

at least one operator is necessary throughout this period, a desire for further economy recently led the company to change the control of the station from manual to automatic.

As it exists at present, the equipment consists of the original 850-kv.a. General Electric Co. synchronous generator driven by an S. Morgan Smith water wheel, a Woodward oil pressure governor that has been changed over for automatic operation, and an automatic control equipment designed for either remote or local control. The generator is so connected that it ties in with the power system of the Northern New York Utilities Co., and with a 300-kw. water-wheel driven generator in the mill. Separate lines carry 125-v. direct current power from the mill to the automatic station for operating the control devices during starting, and also to furnish power to run a Brunner air compressor that maintains the compression on the water-wheel brake mechanism. In order to meet the power requirements of the mill, several interesting features have been incorporated in the design of the control equipment, the operation of which is essentially as follows:

Starting is accomplished by closing a switch on the board in the main power station of the mill. When this switch is closed a circuit is completed from the positive to the negative of the 125-v. direct current control bus through a synchronizing motor, which works on the water-wheel governor, the governor solenoid and the various protective devices. The net result of the actuation of the synchronizing motor and the governor solenoid is that the brakes on the water-wheel are released, the gates are opened and the generator starts to revolve. As it approaches synchronous speed, the exciter voltage, in building up to a predetermined value, actuates contactors that transfer the control devices from the 125-v. direct current control power circuit to a circuit supplied with power by the exciter itself, thus rendering further operation independent of the 125-v. power supply.

In the main station the operator holds the master switch closed until he sees an indication on the voltmeter that is across the automatically controlled generator. Knowing from this indication that the exciter at the automatically controlled station is able to supply control current to complete the starting sequence of the generator, he is ready to synchronize the latter preparatory to putting it on the line. Synchronizing is accomplished by manipulation of the master element, which controls the synchronizing motor in the automatic station. This motor raises or lowers the governor, causing it to open or shut the gates, and thus control the speed of the water-wheel. When the generator is synchronized, the operator connects it to the lines by closing a triple pole oil circuit breaker.

Normally, the station is shut down by pulling the master switch into the stopping position. This completes the circuit through the contacts of a limit switch, which breaks the connection to the synchronizing motor, causing the gates to close, and the machine to shut down. As the gates approach the full closed position, valves in the air lines to the brakes are operated, setting the brakes and stopping the wheel. The wheel is thus prevented from turning over in case the gates should leak slightly, or creep open a small amount. In case of trouble the system may also be shut down automatically by any one of a number of protective devices, which guard against severe overload, reverse power, overspeed, over voltage, overheated bearings on the generator, overheated windings, failure of field, and low oil pressure. A float switch in the forebay, which opens its contacts when the water level falls below a predetermined value, indicates the low level by means of lamps on the main switchboard at the mill.

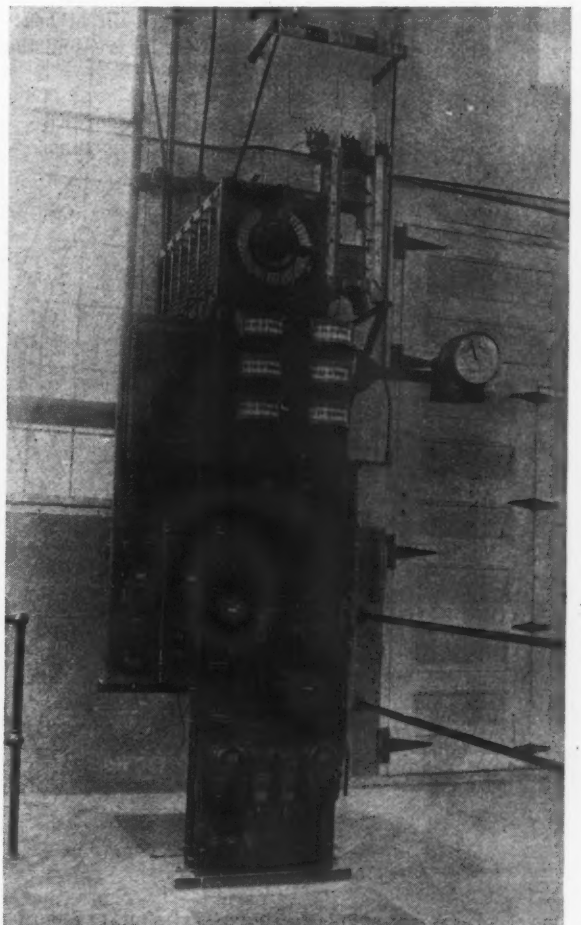


FIG. 2. SWITCHBOARD FOR 850-KV.A. GENERATOR AFTER HAVING BEEN CHANGED OVER FOR AUTOMATIC OPERATION

By means of the combination of the synchronizing motor and the float switch, the operator in the main station is given the opportunity of running the automatic station to the best advantage. By changing the governor setting through the synchronizing motor, he can regulate the output of the generator so as to suit his needs exactly. For instance, if, by watching the power demand of the mill, he sees a peak coming, he can make the automatic station take it by increasing the output of the generator. Conversely, when the load falls off, he can relieve the generator of some of its load, thus conserving the water in the forebay. The float switch warns against running the generator when the water is at too low a level for proper operation. The economic advantages of such an installation at a site where only a small amount of power is available are obvious.

Important Discussions Presented Before A. S. M. E.

EFFICIENT USE OF STOKER EQUIPMENT, ASH HANDLING, ECONOMIC POSITION OF THE ENGINEER AND WORK OF RESEARCH COMMITTEES WERE OUTSTANDING FEATURES OF 43RD ANNUAL MEETING AT NEW YORK

SUBJECTS presented before the forty-third annual meeting of the American Society of Mechanical Engineers at New York on Dec. 4 to 7, which were of the most interest to engineers in the power field, consisted mainly in those papers which had a direct bearing on efficient plant operation. For this reason the symposium on stokers and a presentation of modern methods of ash handling called forth the most spirited discussion.

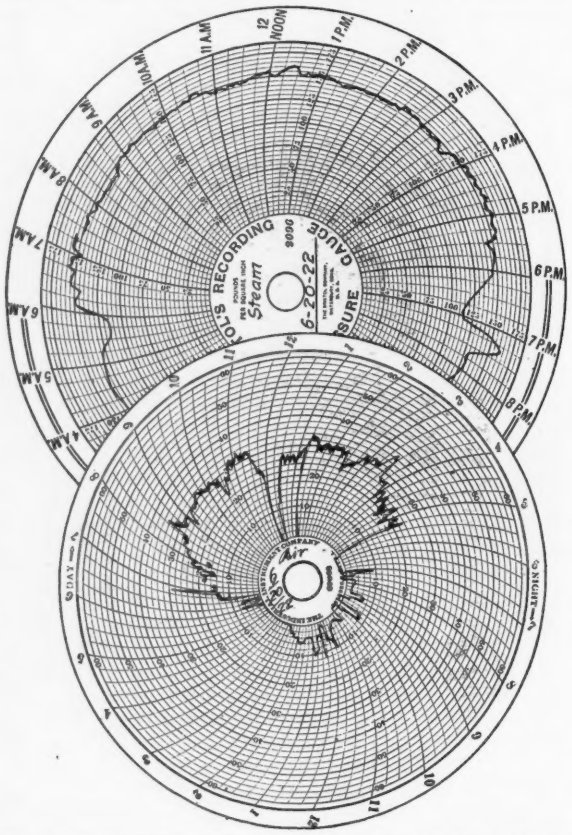


FIG. 1. STEAM PRESSURE AND AIR PRESSURE CHARTS FROM AN INSTALLATION WITH AUTOMATIC DRAFT CONTROL

As at former annual meetings there was a wealth of information presented relating to the activities of the research committee and the work which is being undertaken by committees in revising the various codes of the society. Public hearings were held on revisions for the boiler code and power test code for feed water heaters and reciprocating pumps. Considerable study has been undertaken by the research committee on the flow of gases through orifices and the effect of pulsations on the accuracy of measuring devices. Two papers on these subjects attracted attention because of their value in connection with the design and use of flow meters.

Dexter S. Kimball, retiring president of the society, in his presidential address struck the keynote of a new line of thinking in regard to the position of the engineer as related to general business administration. He asserted that there are three distinct types of leadership; military, legal and business. Neither of the first two types has taken the well being of the industrial group into consideration as much as possibly has the business element of leadership. He pointed out that the engineer is peculiarly fitted, through the scientific method of approach, to develop along the lines of business leadership. Engineers, he stated, were taking a more active part in business and affairs of state and must continue to grow in this line of endeavor. This point was further brought out at the joint meeting with the American Economic Association.

SHOULD AUTOMATIC REGULATING EQUIPMENT BE USED WITH STOKERS?

IN CONNECTION with the symposium on stokers a discussion arose as to value of automatic regulating equipment which is frequently used on stoker fired boilers. W. N. Polakov, consulting engineer, stated that a stoker is automatic only as far as it substitutes mechanical power for muscle while the regulating equipment controls only detached factors. The apparatus is usually lagging behind the actual conditions and therefore the best conditions could not be maintained. He asserted that no machine could replace human intelligence and that the human factor must also be considered. Mr. Polakov cited cases where the plant efficiency was increased by careful training of the operators although in every other way the plants were operating under the same conditions of load and regulating apparatus. He stated that the best stoker is the one that permits the most opportunity for manual control.

J. B. Crane, of the Geo. T. Ladd Co., cited an instance where a saving of 20 T. of coal a day was made by taking half of a 16 boiler installation off of the regulator control. He asserted that this was due to the fact that the regulating equipment works on a basis of change in pressure and that the air supply is subject to large variations. By placing half of the boilers under steady working conditions and letting the other half of the installation take care of the pressure variation by automatic regulation the operating results were better in this particular case. In this installation the regulating equipment operated the entire battery and was not unit operation.

W. J. Wohlenberg, of Yale University, pointed out that in a case of parallel operation there are too many factors involved, to consider that regulating equipment is really automatic. Automatic control, he maintained, should be called an aid to the control of combustion rather than to state it was automatic in operation.

Stoker manufacturers are not prejudiced against regulating equipment, but they realize that it is difficult to secure operators intelligent enough to regulate the dampers without getting operators intelligent enough to regulate a regulator, said Sanford Riley. He thought that it is merely a matter of education and training and that gradually the use of such regulating equipment will become more general. T. A. Marsh concurred with

this viewpoint, stating that he believed that automatic regulation will be the next big step in combustion work.

This symposium on stokers was given under the joint auspices of the Fuels Division and the Stoker Manufacturers Association and was presided over by L. P. Breckenridge, of Yale University. Development and Use of Modern Chain Grate Stokers, by T. A. Marsh; Overfeed Stokers of the Inclined Type, by G. I. Bouton; Design and Operation of Underfeed Stokers, by H. F. Lawrence; and Chronological History of Stoker Development to the Present Day, by A. H. Blackburn, were the papers which were presented.

After discussing the need of progressive combustion of the several constituents in coal, and the variations in grate design to handle different coals, T. A. Marsh, of the Green Engineering Co., took up the improvement of chain-grate practice, air tightness, cooling, size of combustion space, etc. He showed how greater boiler capacity can be obtained by increasing grate size or by more intense natural or forced draft such as 0.5 to 0.6 in. for a combustion rate of 40 to 45 lb. per sq. ft. of grate per hour. He stated, however, that high and sudden overloads are best met by forced draft chain grates burning 55 to 60 lb. bituminous coal per square foot per hour with air at 2 in. pressure distributed through compartments between the runs of chain. It was stated that 200 per cent rating can be reached in 8 min. from a short banked fire or in 52 min. from a cold grate by using such equipment.

Development, present construction and method of operation of front and side feed types of inclined overfeed stokers were discussed by G. I. Bouton, of the Murphy Iron Works, in his paper. He described three side-feed stokers with an illustration of a Dutch-oven type of setting. It was stated that 200 per cent of boiler rating can be obtained with 0.3 in. to 0.5 in. draft loss through the fuel bed and that when forced draft is applied, it should be done with proper regard to air circulation and the maintenance of suction above the fire. Three front-feed stokers were also described and an explanation given of combustion control by varying the stroke of the coal pusher and the angle of rotation of the bars.

Emphasis was laid on the importance of proper adjustment of the secondary coal feed to prevent clinker and ash depositing at the lower end of the retorts and on draft control not too responsive to momentary variations in boiler conditions by H. F. Lawrence, of the American Engineering Co., in his paper. In underfeed stokers, he maintained that if insufficient coal is fed from the lower or rear end of the retort, the ash, instead of being carried on the dump plates, is deposited at the lower end of the retorts, and as high fuel-bed temperatures are always obtained, the ash is clinkered and when deposited at this point it blocks the air discharge. After a short interval, fuel from the upper part of the retort, which is not coked, is deposited over this clinker formation and then avalanches on to the dump plates. With this condition of fuel bed, Mr. Lawrence stated that it is impossible to obtain good operating results. With proper strokes of the secondary coal feeding mechanism, this condition can be eliminated.

Mr. Lawrence pointed out that an ideal regulating equipment would be one which controlled all the variable elements in the proper proportion and in exact relation to the load, thereby obtaining a constant steam pressure. Such an equipment would, in addition to controlling the fuel, air supply, and drafts, also be required to control the feed water. Practically all regulating systems, he continued, are controlled by variations in steam pressure. The damper regulator is sensitive to slight changes in steam pressure and unless its action is retarded, hunting will take place, causing rapid and wide variations in the air pressure. Much better fuel economy is obtained by eliminating the rapid fluctuations in air pressure. In Fig. 1 is shown an air pressure and a steam pressure chart from a boiler installation with such equipment.

Fan characteristics, such as shown in Fig. 2, were discussed by Mr. Lawrence. He pointed out that the

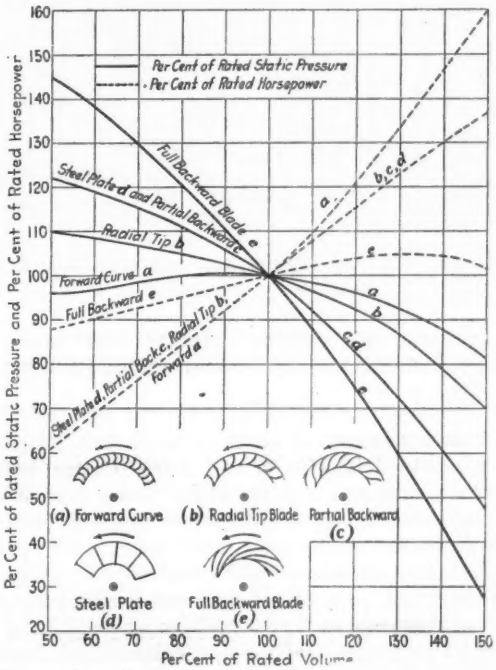

Per Cent of Rated Static Pressure
Per Cent of Rated Horsepower
Per Cent of Rated Static Pressure and Per Cent of Rated Horsepower
Per Cent of Rated Volume
Steel Plate and Partial Backwards
Full Backward Blade e
Radial Tip b
Forward Curve a
Full Backward e
Steel Plated, Partial Backw., Radial Tip b, Forward a
(a) Forward Curve
(b) Radial Tip Blade
Partial Backward (c)
Steel Plate (d)
Full Backward Blade (e)

FIG. 2. FULL BACKWARD BLADE FAN SHOWS BEST CHARACTERISTICS FOR STOKER WORK

full-backward-curved fan with long blades, which is also a high speed fan, has the best characteristics for stoker service. It has a steep static pressure curve together with a comparatively flat horsepower curve, and has the additional characteristic that after reaching the maximum horsepower any further increase in volume due to reduction of static pressure, will reduce the horsepower required.

Coal must be as uniformly sized as possible for the chain grate, asserted T. Maynz, of the Cleveland Electric Illuminating Co. Even then there is apt to be a segregation when the coal is fed onto the grate. He stated that his company had trouble due to the fact that the larger size coal would work toward the edges and also toward the center line of the grate, leaving two lines of finer coal in between. He stated that the operator was looking for reliability, low maintenance cost, and the ability to burn almost any kind of fuel obtainable within a reasonable distance of the plant, in stoker equipment. It was also his opinion that the stoker operator should have the proper instruments in order

to check up on the operating conditions. David Myers, consulting engineer, maintained that the efficiency of any process is equal to the mechanical efficiency of the equipment multiplied by the efficiency of the operators. He also showed that the development of stokers for marine practice had been neglected. Alex. D. Bailey, of the Commonwealth Edison Co., made the statement that increased fuel and equipment costs have forced the use of high capacities. Increase of grate area and additional gas volume have meant additional combustion space. In order to obtain the necessary economic balance, refinements of equipment and methods must be continued. Cost of steam per 1000 lb. evaporated is the real measure of equipment rather than efficiency, asserted J. M. Drabelle, of the Iowa Railway & Light Co.

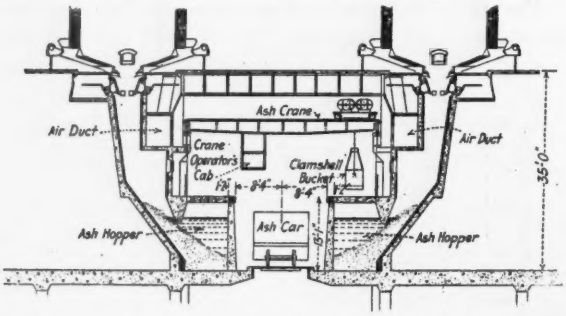


FIG. 3. WATER SEALED ASH PIT USED AT SPRINGDALE STATION OF WEST PENN POWER CO.

Ash Handling Methods Studied

Various methods of handling ashes were presented in a paper by John Hunter and Alfred Cotton, both of whom are connected with the Heine Boiler Co. Design, construction and capacity of hopper ashpits, including their doors and water seals, were taken up. Systems of mechanical conveyance and elevation were described, comprising ash cars, skip hoists and bucket conveyors. Fluid conveyance, as represented by water sluicing and steam jet conveyors, and the particulars of ash breakers and settling basins as well as the final disposition of ash were other points covered.

One method of handling ashes which came in for comment was that which is shown in Fig. 3. This system, which is in operation at the Springdale station of the West Penn Power Co., uses a water sealed ash pit. The ashes are removed by means of a traveling crane and clamshell bucket.

N. E. Funk, of the Philadelphia Electric Co., thought this system rather cumbersome and pointed out that if the crane broke down, difficulty would be experienced in the removal of ashes. It was his opinion that the best system is one where either railroad cars or industrial cars are run into the basement and the ashes loaded. It was his contention that the basement height would have to be little greater than for a sluicing system or for that required by mechanical conveyors. Furthermore, the system offered the maximum freedom possible from breakdowns. He further asserted that two men on one shift could handle the ashes for a 70,000-kw. station operating at a 70 per cent load factor, with the use of two storage battery locomotives. Emergency storage is most important and he objected to the mechanical conveying and fluid systems because a maximum of such storage could not be provided. In the case of the removal of ash with cars the entire section of the basement could be used if necessary and the ashes could be taken out by trucks.

Gas in the basement, due to quenching, is one point that must be guarded against, stated G. E. Bell, of the West Penn Power Co. Proper ventilation of the ash cellar should be provided for. He said that it will be necessary to handle 1000 T. of ashes a day at the Springdale and Windsor stations when present extensions of these plants are completed. Ash disposal was therefore an important problem from his viewpoint. This company has purchased land near the plants and is filling in ravines. A bucket conveyor system will be installed in the near future at a cost of $110,000 which will handle the ashes taken to the ravines. This method of removal will cost about 25 cents a ton as against 75 cents a ton for railroad transportation.

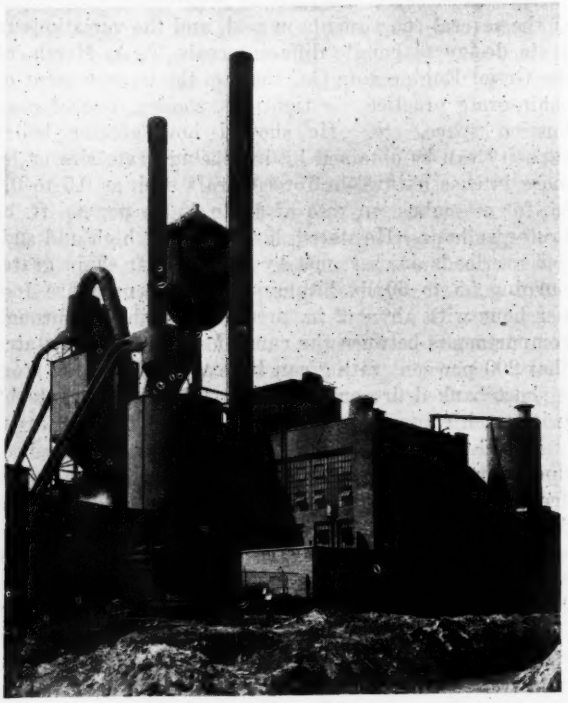


FIG. 4. HOLLOW TILE ASH BUNKERS HAVE A NUMBER OF DISTINCTIVE FEATURES

Ash disposal is an even bigger problem than ash handling, according to I. E. Moultrop, of the Edison Electric Illuminating Co. of Boston. In his opinion, the ash pit should be as large as possible and the less machinery used the better. Such machinery should be of a type that would not shut the plant down in case of a breakdown. He was inclined to favor the use of railroad or industrial cars, as did Mr. Funk.

Don't cut down on headroom for ash pits, was the advice of T. Maynz, of the Cleveland Electric Illuminating Co. Another important point in his estimation was sufficient storage space. His company has a 48-hr. storage capacity for ashes which allows time enough to take care of an emergency. The ashes are handled by a skip hoist and industrial cars.

Some attention was given to the subject of ash bunker design. In Fig. 4 is shown a hollow tile ash bunker

which is used at the plant of the Fisher Body Corporation. These tanks have the advantage that they are fireproof, prevent freezing of wet ash, are acid proof, provide space for steel reinforcing rings within the wall, and have a smooth interior surface. The tiles are laid in cement and are provided with key grooves on their joint faces.

E. H. Tenney, of the Union Electric Light & Power Co., St. Louis, called attention to the fact that overhead ash bins should have a heating coil at the doors so that there would be no danger of freezing.

Feed Water Heating Discussed

At the session of the Power Division presided over by J. H. Lawrence, one subject which attracted spirited discussion was that of feed water heating. Linn Helander, of the Westinghouse Electric & Manufacturing Co., presented a paper on this subject which dealt with the correct feed water temperature from a standpoint of high thermal efficiency. The discussion then worked around to the question of bleeding steam from the turbine for heating purposes and the possibility of driving the auxiliaries by motor drive and eliminating the house turbine.

W. M. Keenan, of Thomas Murray, Inc., stated that they were interested in this question of turbine bleeding in connection with the design of the new Hudson avenue station of the Brooklyn Edison Co. The investigation of the subject had convinced them that the most efficient point for bleeding in either two or three-stage heating was at comparatively high pressures rather than on the vacuum end of the unit. That is about 12 lb. steam for the first stage and about 100 lb. steam for the second stage.

Bleed the main unit to the limit and drive all of the auxiliaries possible with motor drive, O. F. Junggren, of the General Electric Co., asserted. This is an actual aid to the turbine as the congestion of steam on the low pressure end is removed.

According to F. Hodgekinson, of the Westinghouse Electric & Manufacturing Co., the reliability of the steam-driven auxiliaries in case of power failure has been the main argument for the house turbine. He also pointed out several methods for assuring reliability of the auxiliary drive, such as placing an extra generator on the unit with a separate set of busses for supplying the current for electric driven auxiliaries. Another method was the use of the motor generator set with turbine drive on one end. Such a turbine he said need not be particularly efficient as its function is only to supply power in emergencies. It was his opinion that the proper places for bleeding a turbine for four-stage heating were at 140 deg. F. and 200 deg. F. on the low pressure end and 50 lb. and 120 lb. absolute, on the high pressure end.

N. E. Funk did not entirely agree with the practical value of the theoretical considerations. In his opinion simplicity is the key to reliable operation. He said it would be all right if the consulting engineers were available for operating the plants. Even so, he doubted if some of the consulting engineers could think of all the proper things to do in an acute emergency situation.

Another subject which appealed to the interest at this session was the determination of the elasticity of pipe bends through some experiments performed by Sabin Crocker, of the Detroit Edison Co., and S. S. Sanford, of the same company. They showed that present data in handbooks are not accurate for the double-offset expansion U-bend. In Fig. 5 is shown the experimental set up which was used to make their determination. One end of the bend was anchored and pressure applied to other by means of a hydraulic ram. The upward movement of the bend was then measured.

Other papers of interest presented at this session were "Commercial Economy of High Pressure and High Superheat in the Central Station," by G. A. Orrok and W. S. Morrison. This paper was abstracted in the Dec. 1 issue of Power Plant Engineering. Paul W. Thompson, of the Detroit Edison Co., also presented the

FIG. 5. PRESENT DATA ON ELASTICITY OF PIPE BENDS NOT ACCURATE FOR THIS TYPE OF BEND

results of a number of tests on a large type W Stirling boiler made at the Connors Creek power house of that company.

Research was the title of a session which was held under the auspices of the Research Committee and was presided over by Walter Rautenstrauch, of Columbia University. Particular attention was given to the study of steam flow in a paper by H. Judd, of Ohio State University, and D. B. Pheley, of the United States Coast and Geodetic Survey, on Effect of Pulsation on Flow of Gases; another paper by J. M. Spitzglass, of the Republic Flow Meters Co., on Orifice Coefficients.

It was shown by a research sub-committee that sudden steam discharges from boilers do not result in any shocks. This is contrary to the old belief that considerable shock was caused by the sudden opening and closing of safety valves.

At a general session presided over by A. L. Rice, of Power Plant Engineering, a paper was presented by E. W. Noyes and H. V. Sturtevant, both of the Sullivan Machinery Co., on the Size of Dry-Vacuum Pump to Employ in a Given Case.

Numerous suggestions were made in connection with the suggested revisions of the boiler code. It is the intention to submit the proposed revisions and the suggested changes to the society members before final action is taken. In a subsequent issue of Power Plant Engineering these will be considered in some detail.

Few annual meetings of the society have been as productive of practical ideas on the various phases of mechanical engineering. The attendance was large and the interest at the meetings well sustained. The program of social entertainment was carried out with careful attention to the comfort and pleasure of members.

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"1923"

As Father Time drops the curtain on the passing year, it is well to think back over its achievements and disappointments, striving to learn the secret of success of the former and the why of the latter. Thus do we make for progress.

Spite of some serious difficulties, 1922 was a good year and there is every reason to believe that 1923 will be even better. With this, our first issue of the new year, we wish all our good friends full measure of happiness and prosperity for the twelve-month ahead, and for all the years to follow.

What Will 1923 Mean to the Power Industry?

With the beginning of a new year, the question naturally arises among those associated with the business of producing power as to what the future holds for this branch of industry. While a hypothetical question of this kind can never be answered with certainty, there are, however, definite trends which may be interpreted as a basis for a reasonable forecast.

One outstanding statement made by a prominent public utility official at the convention of the Association of Edison Illuminating Companies held in October was that the construction of hydroelectric and steam stations is proceeding at a rate hitherto unknown in industry. In fact, the keynote of this convention was the optimism expressed regarding the growth of the public utility end of the power industry.

This viewpoint was still further borne out by statements made at the Investment Bankers' Convention held in San Francisco during October. It was stated that the territory west of the Rockies will require a billion dollars for hydroelectric and steam plant development during the next ten years. As the expenditures in California alone amounted to $150,000,000 in 1921 and as the 1922 developments were on a large scale, it is entirely probable that $200,000,000 will be used for power developments west of the Rockies during 1923.

Not alone on the west coast do reports of planned developments show that an era of unusual expansion is under way, but from all sections of the country programs calling for increased plant facilities have been outlined. The Commonwealth Edison Co. of Chicago will complete the Calumet station and begin the construction of a new station on the west side, at a cost of over $50,000,000. Some $8,000,000 will be spent by the Brooklyn Edison Co. on the first section of its 400,000-kw. plant. In Ohio, the American Gas & Electric Co. and the Ohio Power Co. have plans for new plants which call for the expenditure of $30,000,000 during the coming year. At Boston, the Edison Electric Illuminating Co. will begin work on a 300,000-kw. plant; while at St. Louis, the Union Electric Light & Power Co. will complete a 60,000-kw. section of its new 240,000-kw. station. In the south, the Southern Power Co. has planned a $16,000,000 program which will add 150,000 kw. to the system and still further tie together the extensive network of transmission lines in that section.

Not alone in the public utility field is this program being made, but in the industrial power field as well.

Plans for hundreds of new plants are reported and improvements to existing plants are almost innumerable.

There seem to be three main reasons behind this growth: First, the increase in the industrial load which has shown the record-breaking daily average of 139,100,000 kw.-hr. for October. During the war, plants were severely taxed to meet the load conditions, yet no construction programs could be undertaken because of the unfavorable conditions. Just after the war, money conditions were unfavorable and business conditions uncertain. As a result, building of new plants was postponed. Now that the load is coming back, it is evident that the extension of power producing facilities must follow.

An easier money situation is the second reason which is advanced to account for the present rapid expansion. In October, the public utility financing amounted to $96,000,000. While a portion of this will be used for refunding previous bond issues, the major portion is for the extension of plant facilities.

High prices for fuel is the third reason for the widespread plans for new plants and the rehabilitation of existing equipment. There is little relief in sight for the present high prices of coal, hence the reduction of a fraction of a pound per kilowatt-hour in the coal consumption makes new and more efficient equipment pay for itself in a short time. The use of powdered coal and fuel oil is also increasing.

From these facts and others which might be cited, it is evident that 1923 should be a year of unusual development in the power field. Every indication points in that direction and it would seem conservative to predict that 1923 will mean even larger opportunities for power plant men than those which were afforded by the work of 1922.

First National Power Show a Success

Although the exhibition held in New York on Dec. 7 to 13 was officially termed the National Exposition of Power and Mechanical Engineering, it might in reality have been called the Power Show, as fully 95 per cent of the equipment shown was for use in the power industry. This at first thought may seem surprising, when it is considered that the field of mechanical engineering also takes in a broad classification of apparatus. Several reasons might be advanced as to the cause of this preponderance of power plant equipment, but the one which probably comes as close as any is that the exhibitors were fully alive to the interest which is being manifested by engineers in apparatus which will improve plant operation and conserve fuel.

Indeed it may be said that the primary purpose of the exposition was to show just what advances have been made in the art of efficient power production. That this purpose was fulfilled seemed to be the consensus of opinion among those who attended the show as well as those who presented exhibits.

From every angle the show may be said to have been successful and certainly the idea deserves the support of the industry. In no other way is it possible for engineering bodies, individual engineers and manufacturers to meet upon a common ground for personal contact such as takes place at such an exhibition.

No doubt, future shows may be made more complete and the attendance enlarged; but considering the initial difficulties encountered, the exhibitors, the management and the executive committee are to be commended for the high standard set, at what we may hope is only the first of such annual expositions.

Automatic Control and the Operative

Every day, mechanical geniuses bring out new devices designed to lessen human labor and to eliminate the uncertainties of the human element. Probably in no industry has the use of mechanical labor saving equipment developed farther than in the power plant. In the boiler room, particularly, the past 20 yr. has seen a change in labor conditions from a sweat shop filled with overtaxed firemen whose principal duty was to keep the furnace supplied with coal, to an attractive work place where control of equipment is largely automatic and manual labor has but a small place.

This is undoubtedly progress in the right direction; but with this progress, it must not be forgotten that equipment based on scientific principles requires an attendant who thoroughly understands all these principles to get the most out of this equipment. We can hardly expect the fireman of 20 yr. ago to handle a modern boiler plant without educating him to present day equipment. He needs more than the mere instructions how to start, stop and adjust the devices. He must be instructed from the ground up on the underlying scientific principles, the whys and wherefores of every device under his care.

This was brought out quite forcibly in a discussion at the A. S. M. E. meeting, where it was stated that it requires as much intelligence to regulate automatic combustion regulators as it does to regulate the dampers themselves. This can readily be appreciated, but the automatic device does not require constant attention and gives the attendant opportunity to look after more equipment and thus cut down appreciably the necessary operating force.

We cannot get away from the fact that efficiency and economy in the power plant are dependent to a very large extent upon the intelligence used by those who operate the plant. It is not so much a question of individual output as quality of work. With automatic regulation and mechanical handling of materials comes a reduction in the number of employes, but with this must also come increased intelligence on the part of operatives.

Acknowledgment

In the course of preparing this issue of Power Plant Engineering for publication, many sources of information have been called upon; principal among which were the works of eminent engineering authors, proceedings of engineering societies and manufacturers of equipment used in the boiler room. The scope of the subject covered is so broad that it was found impracticable to describe in detail all the different makes of the various equipment which made it necessary to confine the descriptive articles to types only. Much of the information secured from various sources has been so interwoven that credit for the original data could not readily be given in the text matter and we take this method of expressing our appreciation to those who have so generously aided in the preparation of this issue.

Bill and I See the Power Show

We Carry Away a Suitcase Full of Literature and Learn a Lot of Things About Power Equipment. By a Chief Engineer

"NOW THE thing to do," said Bill as we ambled up Lexington Ave. toward the Grand Central Palace, where the Power Show was to be held, "is to take in this affair methodically—up one aisle and down another is my motto. Some fellows duck around and see only the more exciting stuff while back in some corner an insignificant little outfit may have some dope that's worth something to you. Let me do the talking and you jot down a few notes and when we get back home we'll tell the boys all about it."

"Suits me," I replied, "you're the chief on this trip."

We were a bit dazzled by the size of the layout when we entered the Grand Central Palace, as neither of us had ever been to a show at this place. It was a job we had cut out for ourselves, but off we started.

"Hello," exclaimed Bill, "what have we here?" as we entered the booth of the Edwin Burhorn Co., of New York. C. A. Harry explained the exhibit, which consisted of a model of a cooling tower known as their "small tower." It seems that this tower is built for small plants where the amount of water required for cooling does not exceed 20 gal. per min.

"Do you make larger towers?" inquired Bill. "Yes, we have them installed up to 6000 gal. a min.," replied our host.

I knew how Bill was when he got started, so I dragged him out and we stopped at the exhibit of the American Refractories Co., of Pittsburgh. A. F. Greaves-Walker, general production manager, explained that although they had been making refractories since 1906, for all classes of high temperature work, they had never really tackled the boiler problem until rather recently. The demand for high grade refractories had led them into this field.

Our next stop was at the Vincent-Gilson Co. booth. This organization represents the Diamond Power Specialty Co., Carling Turbine Blower Co., The Engineer Co., Falls automatic engine stops, and Tracy steam purifiers, in the New York territory.

Bill was particularly interested in the Diamond soot blowers, one of which was set up in a section of furnace wall to demonstrate the method of operation, and we also looked over one of the Carling blowers.

Next a large ash-hopper in The Allen-Sherman-Hoff Co. exhibit caught our attention, so we made for this exhibit. This ash-hopper is of cast iron construction, arranged for continuous quenching of ashes. The gentleman in charge showed us how a water seal built up on the sliding door, to seal the hopper against escaping gas, caused by the quenching. This company also builds a line of ash-bunkers.

"What kind of a toy is this," exclaimed Bill, as his eye took in a small hand operated stoker which was being exhibited by the Gibby Engineering Co., of Boston. "Hardly a toy," commented Chas. L. Weeks, their New England representative, "as we build these installations up to 750 hp." He went on to show us how this hand operated stoker offered a possibility of dumping the front and rear halves of the fire independently, and was also built in such a way that the grate surface was made up of a series of detachable blocks which could be moved independently of each other and could be replaced if necessary without disturbing the fire. The Pyramid Iron Products Corporation, agents for the Gibby Co., in the New York territory, were also demonstrating another grate of slightly different design, known as the "Pyramid" grate. In this case, the grate surface appeared to be a series of flat top pyramids, the air being introduced from four rectangular holes on the side. The arrangement, according to the demonstrator, allowed the use of a stronger blast without danger of blowing holes through the fire bed.

Next in line was the equipment shown by the London Steam Turbine Co., of Troy, N. Y. What was of particular interest to Bill was their steam turbine stoker drive. This is a geared unit, and any desired range of speeds necessary for correct stoker operating conditions can be maintained. Morris R. Sibley, who gave us the information, also pointed out features of their regular line of geared turbines for general service.

"Now here is an old friend of mine," commented Bill, as we turned in at the Sanford Riley Stoker Co. layout. As soon as we had introduced ourselves to N. H. Phelps, who was in charge, Bill promptly wanted to know what was the newest thing in stokers. Mr. Phelps made the statement that they were making a feature of their new lateral retort stoker which is of the underfeed side dump type. "It is designed," he continued, "for boilers of intermediate size of, say, 200 to 600 hp. and is a stoker which is capable of high continuous rating. It is the only under-feed stoker of the side dump type." Mr. Phelps was enthusiastic about the prospects for business in the power field when we asked his opinion about general business conditions.

"What's a radiant heat superheater?" asked Bill, as we were looking at this piece of apparatus in the booth of the Power Specialty Co. Pell W. Foster explained at some length that the radiant heat superheater element consisted of a seamless steel tube to the outside of which heavy solid cast-iron rings are snugly fitted, the individual rings having the flat side exposed to the furnace. Only this flat side is exposed to the radiant heat, the heating surface being built in and forming a part of one or more of the furnace walls. At intervals, the cast-iron rings are anchored to heavy structural members to resist distortion. A steel casing back of the elements forms a solid wall and the space between the casings and elements is filled with insulated material. This is something new in the way of superheater design and both Bill and myself were much interested.

Another item of interest in that exhibit was their steel tube economizer, which has a series of cast-iron rings shrunk on the tubes. One rather unusual feature of this economizer is that the surfaces are kept clean while the economizer is operating, by spraying with water from pipes which are mounted above the banks of tubes. According to Mr. Foster, about one-fifth of the tube section is cleaned at a time, it being only neces-

sary to keep the water spray on for about one minute in each case.

Filters and lubricators, lubricating appliances, oil pumps, and oil storage tanks with self-measuring pumps were on exhibition at the booth of S. F. Bowser & Co., of Fort Wayne, Ind. K. E. Paulus showed us around

1. Model of a cooling tower was the feature of the Edwin Burhorn Co. exhibit
2. Cast iron ash hopper with continuous quenching feature shown by Allen, Sherman, Hoff Co.
3. Turbine drive for stoker work a part of London Steam Turbine Co. exhibit
4. Radiant superheater and steel tube economizer presented by Power Specialty Co.
5. Effect of pipe coverings in reducing radiation losses demonstrated by Keasbey & Mattison Co.
6. Automatic high pressure boiler feeder and line of valves shown by Kieley & Mueller

and told us that business was increasing right along and was better now than it had been for two years.

"What kind of a steam heating plant is this?" asked Bill of Mr. Barrett, of the Keasbey-Mattison Co., as we looked over an exhibit which consisted of a small gas fired boiler connected up to a series of pipes which were covered with heat insulating tubes of varying thicknesses. "What we are trying to show here," remarked Mr. Barrett, "is the radiation loss due to lack of proper pipe coverings. You will notice that with 15 lb. steam the surface temperature on the ½-in. thick air cell covering is 114 deg. F., while with the 1-in. thick covering it is 101 deg. F. With the 1-in., 85 per cent magnesia covering the temperature drops to 91 deg. and with the 2-in. magnesia covering, 77 deg. and with the 3-in. covering to 70 deg. F. The room temperature at the present time is 62 deg. As these temperatures are somewhat of an indication of the radiation loss, you can readily see the value of a first-class pipe covering."

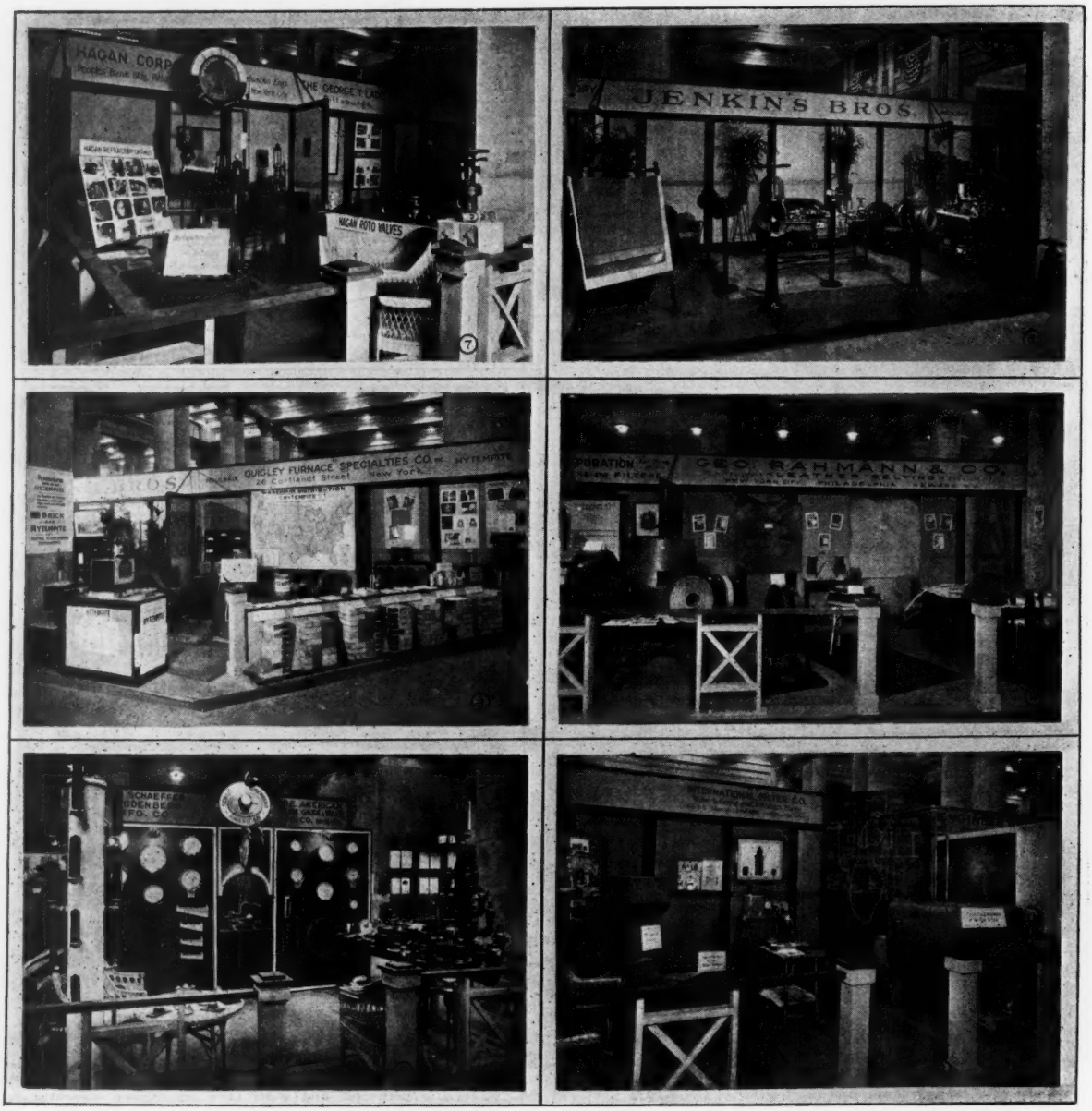
"You have sold me," said Bill, "and when I get

home I'll look the old plant over and see what we can do along this line."

Our next stop was at the booth of the Paulsen-Spence Co., which was representing the A. W. Cash Co., of Decatur, Ill., manufacturers of pressure reduction and regulating valves. This same organization is also representing the Kelly Valve Co., of Muskegon, Mich., which makes a line of self-grinding valves. In this booth we also saw an installation of a complete two trap system for returning condensate to the boiler without the use of pumps or injectors. The condensate is returned by gravity from the second trap in the system.

Temperature control by means of an all metal thermostat was shown by Bishop & Babcock Co., of Cleveland, Ohio. This has particular application to heating and ventilating systems where the thermostat operates the various duct dampers and also the control valve.

Kieley & Mueller showed us some of their late appliances which were not given in their catalog. Automatic high pressure boiler feeders, back pressure valves for marine service, high pressure reducing valves with piston lever control, were among these features.



7. Proper combustion control was emphasized by the Hagan Corporation
8. Jenkins Bros. showed a part of their line of valves
9. Tests on refractories were run by the Quigley Furnace Specialties Co.
10. Many types of belting made up the exhibit of George Rahmann & Co.
11. Complete line of power plant instruments comprised the exhibit of Schaeffer & Budenberg Mfg. Co.
12. Methods of water treatment were explained by the International Filter Co.

Now, when Bill gets out on a trip of this kind, he usually reverts to the days of his early childhood, and is therefore much attracted by anything that is either operating or that is shown in model form. It was all that I could do to drag him away from the exhibit of the Connelly Boiler Co., of Cleveland, where they were show-

ing two models of their boilers under actual steaming conditions. Bill looked in the little glass windows at the ends of the drums and vowed that though he had been operating boilers for 20 yr., it was the first time he had ever had a chance really to see what was going on inside.

"Do you know," remarked Bill, "I believe the plant in the future will have to provide tennis courts or a golf course so that the operators will have something to do to while away their time." This observation of Bill's was produced by the exhibit of the Hagan Corporation, of Pittsburgh, which showed how combustion control apparatus functions. As explained by T. A. Peebles, who is chief engineer for the company, the master control opens up the steam valve to the turbo fan and speeds up the stoker drive, adjusts the boiler damper, and the secondary control compensates for the varying fuel bed by adjusting the inlet air damper under each stoker. "It does just about everything but think," commented Bill, "and it probably does that better than some of the fellows that I have working for me."

We looked over the photographs and blueprints of the boiler installation at the River Rouge plant of the Ford Motor Co. with a lot of interest. These were shown in connection with the Geo. T. Ladd Co. exhibit, as this concern furnished the original installation of boilers, and also an additional set which are soon to be installed. W. R. Holmes, of the New York office, gave us a number of points of interest regarding these boilers.

At the exhibit of Jenkins Bros. we were interested in the line of cast steel gate valves, rapid action globe valves, marine valves, air guns for cleaning purposes, pump valves, fire line valves and sheet packing, etc. As this concern also distributes the products of the Mason Regulator Co. in the eastern territory, we had an opportunity to look over the damper regulators, pump governors and reducing valves which are made by this concern.

Now, as I said before, as soon as Bill gets around to something that looks like it was made for a toy he becomes very hard to control, and I had some difficulty in getting him past the Quigley Furnace Specialties Co. demonstration of the bonding qualities, under severe temperature changes, of their Hytempite. For this purpose they were using a small electric furnace and after the specimens had been heated they were plunged into cold water.

"We have been having a lot of trouble with clinkers on our furnace walls," said Bill, as we carefully examined a section of furnace wall which had been built up by the Bernitz Furnace Appliance Co. out of perforated blocks. A. E. Smith told us how, through the introduction of air, along the furnace wall, within the clinker zone, the adherence of clinker was prevented. The air is bypassed from the forced draft air chamber. The method is of special value in furnaces equipped with under-feed stokers and forced draft, where high ratings are obtained. In such cases, the settings are apt to deteriorate rapidly, due to the intensive heat and to the adhesion of clinker.

Another type of hand operated grate was shown by the Erdman Forced Draft Co., of New York. According to C. C. Rossire, the air under the grate is distributed from a number of distributing chambers.

"Well, I guess this is the first water treatment exhibit that we have seen," remarked Bill, as I. L. Birner, of the Graver Corporation, showed us, by means of a large diagram hung in their exhibit, just how their hot process method of water softening functioned. "Besides this hot process method," stated Mr. Birner, "we have a cold process method known as our continuous softener, which is used for raw water ice plants, and we also build the Zeolite softener, which is used in textile and laundry work. You will also note that we have a pressure filter which is used for water purification in municipal plants and work of like character."

Belting of all kinds, shapes, sizes and varieties was shown by the Geo. Rahmann Co., of New York City. Chrome, oak, and waterproof, and a combination chrome and oak belting were the especial types shown. In the next booth the Leather Belting Exchange, which is an organization supported by the various manufacturers of belting, showed a machine used in making belt tests to determine the amount of slip. R. F. Jones, who had this in charge, stated that the machine consisted of a dynomometer which was driven by a motor through the belt to be tested. An extension of the motor shaft carried a two-brush commutator which made connections through another commutator and brushes on the dynomometer. As both machines rotated, a light mounted on a plate on the dynomometer shaft was lighted by each revolution of the driving motor. Due to the slip of the belt, the light did not light in the same relative position at each revolution and therefore the ring of illumination seemed to rotate at a certain speed, according to the amount of slip.

Bill is always interested in instruments, as that is somewhat of a hobby of his, and he is never happier than when testing an instrument or installing some new device for checking up on his plant operation. We therefore inspected with some care the line of power plant instruments which were shown by the Schaeffer & Budenberg Mfg. Co., and the American Steam Gage & Valve Mfg. Co. Division. G. A. Binz also called our attention to the American steam trap and the line of pop safety and water relief valves.

Another method of water softening which caught our attention was that shown by the International Filter Co., of Chicago. What appealed to us was that part of the equipment was shown in large diagrammatic layout, and the chemical mixer, of the variable rate type, was set up and in operation on the floor. At the proper points, the piping entered the large diagram which gave one a very good idea of the general arrangement of this equipment. O. A. DeCelle, sales manager, pointed out an automatic water control for constant rate softeners for use in the cold process method. A dry chemical feed for municipal water supply work was also shown.

"Now, this is what I call a good stunt," Bill ejaculated, as his attention was caught by a monolithic type of baffle wall which was shown by The Engineer Co., of New York. This baffle which is known as the "Turner" is built by pouring a high temperature cement in a form which is set up corresponding to the desired baffle wall thickness. It is therefore possible to place a wall in any desired position with relation to the tubes. L. Faber, who talked with Bill, gave us some idea of how the Enco oil burner worked and pointed out that it was a low pressure burner operating

at not over 30 lb. pressure. "This means," he said, "that it is possible to use the low pressure pumps, heaters, etc." "You will also notice," remarked Mr. Faber, "that we are showing our balanced draft, furnace pressure regulator."

"Well, this is what I call a real model," was Bill's comment when we looked over the Loree coal breaker, which was shown by the Hudson Coal Co. We were informed by one of the men in charge that this breaker has a capacity of 6000 tons of coal every eight hours, and is the largest capacity breaker in the world.

When H. J. Kilroy, of the De Laval Steam Turbine Co., told Bill that the 1½ hp. turbo generator set for headlight service ran at a speed of 39,000 r.p.m., Bill's eyes bulged out. "Of course," Mr. Kilroy went on to say, "this small reduction gear cuts down the speed of the generator within the range of good commutation. For the larger machines of single stage type, say about 500 hp., the speed will be in the neighborhood of about 12,000 r.p.m. You will notice that we are also showing a double helical reduction gear for pumps, generators, blowers, and other such applications. Another feature is a single stage double suction pump for operation on a 200-ft. head with a capacity of 2000 gal. per min. and a two-stage series pump for operation on a 300 ft. head with a capacity of 900 gal. per min. or 1750 r.p.m."

In the same booth we looked over the exhibit of the De Laval Separator Co. which is a separate organization from the turbine company, but tied up with the same general interests. This company had its transformer oil and fuel oil purifiers on exhibition. "Not much different from a cream separator," remarked Bill, and S. Moss, who was giving us the information, smilingly agreed that the general principles of action were somewhat similar.

"This instrument is something new, is it not?" asked Bill, of W. S. L. Wharton, of the H. S. B. W.-Cochrane Corporation, as we looked at their flow meter. "Yes, you are right," replied Mr. Wharton, "this is the flow meter that uses the tilting manometer principle of action. You will see that the pressure tubes from the orifice are brought into the tilting manometer by torsion tubes which are twisted slightly when the manometer tilts. You will also notice," he continued, "that we are showing our V-notch meter in operation, and also the Cochrane weighing meter which operates on the dumping bucket principle. The bucket is a two-compartment arrangement so that when the measuring compartment is emptying the other compartment takes care of the flow during that time interval. Here we have a chemical feeding set for the hot process water softening system. This feeder is controlled automatically according to the amount of water flowing through the softener, that is, more chemical is fed into the system by the flow proportioning valve in accordance with operating conditions. The chemical mixture is simply dumped into the agitating tank and a circulating pump keeps it thoroughly mixed. The other pump pumps the chemical into the softener through the flow control valve which is in the chemical supply line to the softener."

"What kind of an outfit is this," asked Bill, as he noticed a valve of somewhat peculiar construction which seemed to be tied up with an electrical device of some sort. "That," replied Mr. Wharton, "is the Cochrane multi-port valve for remote electrical control."

Next in line was the Nash Engineering Co., of South Norwalk, Conn., where G. R. Wright told us some things about their general line of pumps for heating systems. These consisted of condensate pumps, vacuum return line pumps, industrial air compressors and vacuum pumps. They also showed a vacuum regulator.

"Here are those electric flow meters such as Jake has over in his plant," remarked Bill as we stopped at the exhibit of the Republic Flow Meters Co., of Chicago. Bill asked G. L. Hendrickson to explain the principles of operation of this type of meter. "Up to the point of registering the differential pressures, this meter is similar in action to other mercury manometer types of instruments," remarked Mr. Hendrickson, "but you will notice that as the mercury rises in this chamber, due to a change in flow, it short-circuits a series of contact rods which changes the resistance of an electrical circuit. The current in this circuit therefore changes and is proportional to the flow of fluid or steam in the pipes. In this way, it is possible to measure the flow by means of electrical instruments. Besides our regular line of flow meters we are also showing our new combination flow meter, CO_2, and flue gas recorder."

Passing on to the next booth, Bill was particularly interested in a model which showed the layout of condensing equipment as applied to a 5000-kw. turbine unit. The Wheeler Condenser & Engineering Co., of Carteret, N. J., also showed the method of operation of its steam jet air pump. Another model showed a cooling tower for a 1000-kw. condensing unit. Both models shown were made to a scale of 1 in. to the foot.

"Suspended arches have always been a rather sore point with me," remarked Bill to R. J. Himmelright, of the American Arch Co., "on account of a lot of trouble jobs that I have had to do on Sunday."

"Well, I don't doubt that," replied Mr. Himmelright, "but we, of course, believe that our construction will eliminate just the kind of troubles which you have had. You will notice that the suspension is all out of the heat zone and is not embedded in the refractory material. Expansion and contraction is taken care of by a series of compression springs which exert a slight lateral pressure against the floating skews and the joints are maintained air-tight regardless of the operating conditions." "Well, it looks good," remarked Bill; "possibly we shall have an opportunity of trying it out."

We now had an opportunity to look over the Manning, Maxwell & Moore Co.'s line of Ashcroft gages, Consolidated safety valves, Metropolitan injectors, Hancock inspirators, and Hancock valves. Mr. Miller, who gave us the information, also called our attention to the Reeves variable speed transmission which is used for stoker drive. One of the pulleys in this drive is a V-notch type, the speed variation being obtained by changing the center distance between the two pulleys. This variation is taken care of by hooking it up to some type of damper control regulator.

"Well, this is quite an exhibit," commented Bill appraisingly, as we looked in on the International Combustion Engineering Corporation. "Some of our old friends, too," observed Bill, as he noticed the signs of

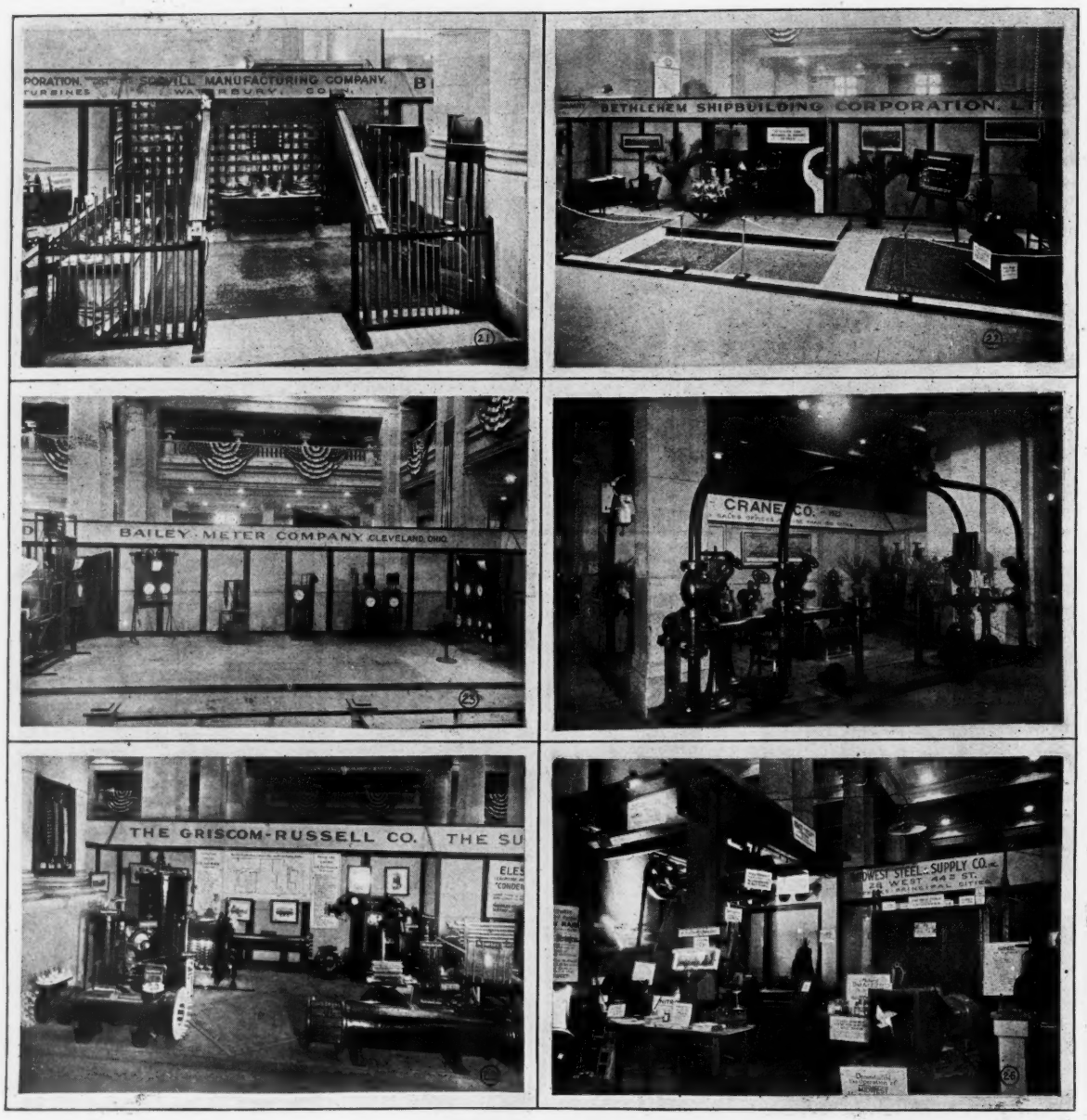
ENGINEER COMPANY
LAVAL SEPARATOR CO.
OIL PURIFIERS
H.S.B.W. COCHRANE CORPORATION
Nash Engineering Company
REPUBLIC FLOW METERS CO.
CHICAGO, ILLINOIS
FLOW METERS and CO2 RECORDERS
WHEELER CONDENSER & ENGINEERING CO.
MAIN OFFICE & WORKS CARTERET, N.J.
AMERICAN ARCH COMPANY, INC.
MANNING, MAXWELL & MOORE
NEW YORK
The American Arch Company has furnished arches in locomotive and power work to the extent of 65,054,500 H.P.
THE BUSY ARCH OF THE SHOW
Just look what we have done
for the first ten months of
this year for locomotive and power
arches we furnish special high
grade refractory shapes equivalent
to 33,694,350 9" brick.
NATIONAL COMBUSTION ENGINEERING CO.

13. The Engineer Company featured Turner baffles, Enco oil burners and a balance draft furnace pressure regulator
14. Oil purification by the use of separators was shown by De Laval Separator Co.
15. Various types of meters and a chemical feeding set were demonstrated by the H. S. B. W.-Cochrane Corpn.
16. Pumps for heating systems made up the exhibit of the Nash Engineering Co.
17. Electric flow meters were shown by the Republic Flow Meters Co.
18. Wheeler Condenser & Engineering Co. used a model to show how condensing equipment is arranged
19. Suspended arch construction was featured by the American Arch Co.
20. International Combustion Engineering Co. had a large exhibit showing their products

the Green Engineering Co., Combustion Engineering Co., and the Lopulco pulverized fuel systems.

One of the men took us in tow and we looked over the Coxe stoker, which is of the forced draft traveling grate type, and we also saw a working model of the Green chain grate. An underfeed single retort stoker,

Returning to the other side of the aisle, we took in the demonstration of the Coppus Engineering Co., of Worcester, Mass. Here were shown forced draft blowers, turbo boiler feed pumps, impulse turbines, and a 20-in. double-stage 4000 r.p.m. turbine which was rated at 50 hp.



21. Brass and brass products made up the exhibit of the Scovill Mfg. Co.
22. Mechanical oil burning equipment and feed pumps shown by Bethlehem Shipbuilding Corpn.
23. Small boiler used to operate the various types of Bailey meters
24. Assorted line of fittings shown by the Crane Co.
25. Methods of bleeding turbines for feed water heating made up a part of the Griscom-Russell Co. exhibit
26. Unit air filters and fastenings for transmission equipment were of interest at the Midwest Steel & Supply Co., exhibit

known as their type "E," was also shown. As this company also handles the Lopulco pulverized coal system, we were interested in one of these burners which was shown. One notable installation of this system is at the River Rouge plant of the Ford Motor Co. We also looked over an installation of Quinn oil burning equipment which was set up in a furnace with pumping and heating equipment attached.

Continuing on our way, we were impressed by the rather elaborate exhibit of brass and brass products such as Admiralty condenser tubing, which was shown by the Scovill Mfg. Co., of Waterbury, Conn.

"I presume this apparatus must be for marine service," remarked Bill as we approached the booth of the Bethlehem Ship Building Corporation. "Not by any means," explained A. B. Reynolds, "we have a large

number of our Dahl mechanical oil burning systems in well known power plants. You will notice," he continued, "that we have developed a new swinging front which may be used both for natural and forced draft. This front may be swung aside without taking it down, which allows easy access to the furnace. We would also call your attention to the Weir turbo feed pumps which have been used for a number of years abroad but which have only recently been placed on the market in this country, and the same is true with the Weir reciprocating feed pump."

At the Bailey Meter Co. exhibit, Bill could have spent at least a half day without being bored, for he was very much interested in the layout of instruments, all of which were in operation. A 2-hp. boiler built to ⅛ scale of a 1000-hp. water tube boiler was used to show the operation of a multi-pointer gage. This gage showed the steam pressure, steam temperature, the gas pressure at several points, and the pressure of the city water supply.

Mr. Bailey, who happened to be in the exhibit at the time, showed us around and called our attention to the V-notch Weir meter with a float operated recorder, which was worked out to give uniform graduation on the chart. We looked over this instrument in some detail and then our attention was caught by a series of glass tubes connected up to a section of glass pipe which had a glass plate orifice in it. "This arrangement," explained Mr. Bailey, "is to show the effect of a plate orifice and how the differential pressure is produced. You will note that the variation in the water level in these various tubes shows that the actual flow in the pipe is somewhat similar in form to the shape of a venturi meter. This type of orifice is being used quite extensively in flow meter work with accurate results.

We were also interested in a tachometer which operated on a differential pressure principle. The pressure differential is created by a whirling tube, the air being thrown out by centrifugal action and the difference in pressure is measured on the indicating dial. A density recorder and a specific gravity recorder were also shown. The specific gravity recorder compensates for temperature and therefore records the true specific gravity. A coal meter of the Vane type was also shown.

We now turned our attention to the exhibit of the Crane Co., of Chicago, where W. L. Oswald showed us some examples of the class of valves and fittings which are produced by this company. Although this exhibit was of considerable interest, we hastened on because the afternoon was rapidly passing.

We stopped for a few moments at the C. B. Nicholson Co. booth where they were showing the Connery method of smoke breeching construction. This type of construction eliminates the angle irons as the plates are V-bent and fastened together. It is said that this affords a stiffer construction and also allows for expansion.

Here's a rather neat little outfit," commented Bill, as we saw the model of a skip hoist which was shown by the R. H. Beaumont Co., of Philadelphia. This working model showed how a skip hoist may be used in a coal handling scheme of a power plant by building a coal bunker at the end of the plant, using scrapers to pull the coal up to the skip hoist and then hoisting into the bunker.

At the exhibit of the Griscom-Russell Co., of New York, Stanley Brown showed us how the Reilley evaporator worked, by means of a large diagrammatic layout of the system. We were also interested in the diagrams of turbine bleeder feed water heating systems. Bill remarked that there seemed to be a tendency toward bleeding at higher pressures than was formerly thought good practice. Mr. Brown verified this viewpoint, stating that in case of three and four-stage meter heating it was becoming quite customary to run well over 100 lb. on the last stage. "In this way," he continued, "it is possible to reduce the steam congestion in the lower stages of the turbines." Mr. Brown also called our attention to the oil heaters, both of the straight type and coil type, and also an expansion joint to go between a turbine and a condenser.

Another exhibit of superheaters which was of interest was that of the Superheater Co., of New York. This organization builds the Elesco superheater, a model of which was shown, together with a section of the header. R. A. Holme called our attention to a portable superheater which is built for industrial use where comparatively small quantities of high temperature steam are needed. Another rather interesting feature of this exhibit was the atmospheric ammonia condenser in which forged return bends are used. In this way all joints are eliminated except those at the inlet and outlet of the condenser.

Passing on, we stopped for a moment to look over the unit air filters which were shown by the Midwest Steel & Supply Co., of New York. They also showed a line of fittings to be used for fastening power transmission equipment.

At the Lunkenheimer Co. exhibit, W. A. Reynolds explained a very interesting pressure controlling device which had been worked out in conjunction with the Payne Dean electric valve control, for the control of pressure between two steam headers operating at different pressures. The control consists of a series of mercury manometer tubes which are mounted in a section of 12-in. pipe, standing about 6 ft. high. There is a mercury column sufficient to maintain the header pressure, and as the mercury column rises and falls it operates a plunger which in turn closes or opens an electrical contact, which causes the valve between the headers to operate. There is a contact mechanism for both the high pressure and the low pressure side which allows the setting of the control for any particular desired operating condition. The Lunkenheimer Co. also showed samples of its different types of safety valves, relief valves, water columns, etc.

"Well," remarked Bill, "let's call it a day," and I agreed with him that as we were so laden down with descriptive literature by this time that we could hardly walk, it would not be a bad idea to call it quits for the time being. However, on our way out we looked in on the M. H. Detrick Co. exhibit where R. D. Foltz showed us some things about their flat suspended arches, and the Detrick-Hagan system of steam jet ash conveying. As the Stewart & Sayers Co. booth was near at hand, we stopped to look at the Northwestern boiler damper control which they were showing, and on our way out the C. W. Hunt Co. exhibit of industrial railroad, and bucket ash conveyors attracted our attention.

Bright and early the next afternoon we were back on the job for a fresh start, and beginning where we left off the Uehling Instrument Co. exhibit of CO and CO_2 recorders first received our attention. F. F. Uehling, who happened to be in the booth at the time, pointed out the recording barometer and vacuum gage which is used as an automatic log for condensers.

Next in line was the booth of the Reading Steel Castings Co., which included the Pratt & Cady Co. and the Reading Valve & Fittings Co. Divisions. J. P. Ferguson showed us some points of interest in connection with a Reading 8-in. cast steel ball bearing gate valve, operated by Deane electric control.

"Now, this is an old friend of mine," I remarked

27. Valves and the Payne Dean method of electric control were shown at the Lunkenheimer exhibit
28. Various types of cast steel valves made up the Reading Steel Casting Co. booth
29. Otis Elevator Co. showed their latest type gearless traction, multivoltage micro drive elevator
30. Walworth Mfg. Co. showed many products for piping installations
31. Pictures of work in the production of oil a feature of Tidewater Oil Co.
32. Electric valve control was featured by The Chapman Valve Mfg. Co.

"Well, the hand stoker seems to be getting in the class of the automatic stoker," remarked Bill, as we stopped to look over the apparatus shown by the Hand Stoker Co. of New York. I was inclined to agree with him, for this stoker has a hopper feed and the fuel bed is worked down by means of tilting grate bars and there is also a hand operated dump at the end of the grate.

casually to Bill, as we approached the layout of the Otis Elevator Co., "as I used to follow the electrical game a few years ago." As all of the men in this booth were pretty busy at the time, I took it upon myself to tell Bill something about how the gearless traction, multivoltage, micro-drive elevator works. This machine automatically stops the car at the floor level.

One of the things which interested us at the Walworth Mfg. Co. exhibit was a new type of automatic water heater for domestic use, although of course we were also interested in the feed water regulator, pressure regulators, automatic relief valves, and other items which they were showing.

Coming to the Edward Valve & Mfg. Co. booth, we looked over their line of forged steel valves and fittings as well as their regular bronze line. R. Sheraton, who took us in tow at this booth, showed us a valve designed for 500 lb. steam working pressure.

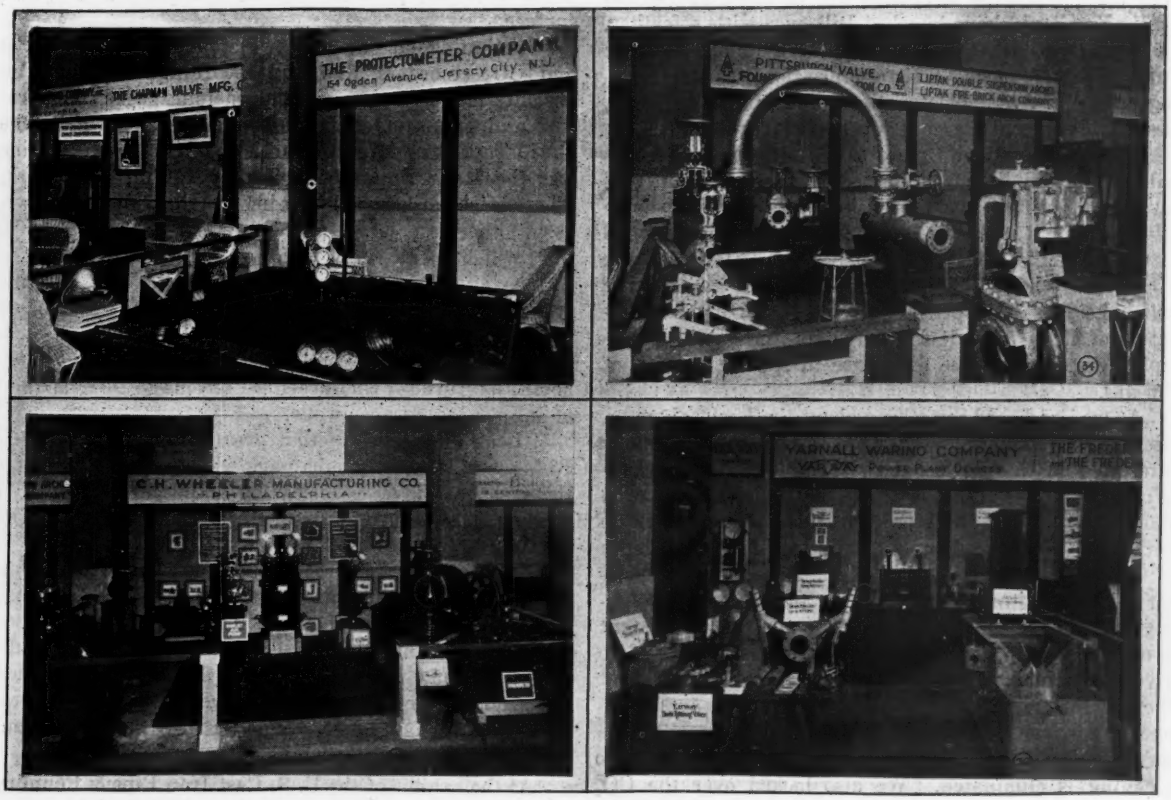
Probably the thing that attracted the most attention at the booth of the Tidewater Oil Co. was a small moving picture outfit which projected a picture on the development and processing of oil. There were also other features including a model oil well, and a mysterious keg out of which oil ran continuously although there seemed to be no visible source of supply.

Continuing on our way, we stopped for a moment at the exhibit of the Ruggles-Klingemann Mfg. Co. where they were showing their step compensator draft and temperature regulator, and L. J. Kimball explained the method of operation for us. As the National Pipe Bending Co. had the adajcent booth, we looked in to see some of the features of their line of feed water heaters, especially in connection with the details of construction which were shown by means of parts and sectional views. Afterwards we crossed the aisle and looked in on the Victor Engineering Co. of Philadelphia, which was showing the Victor steam jet ash conveyor and the Carrick scheme of combustion control.

In talking with C. J. Burrage, of the Chapman Valve Mfg. Co., of Indian Orchard, Mass., the point was mentioned that 24 yr. ago this company installed its first electric control for valves in the Atlantic Station of the Boston Edison Co. Neither Bill nor myself had any idea that electric valve control dated that far back. Mr. Burrage also showed us a cast steel valve designed for 800 lb. working pressure, and built to withstand a temperature of 800 deg. F.

As Bill has had considerable experience with methods of storing coal, he was quite interested in the exhibit of the Protectometer Co. where an instrument for measuring the temperature of a coal pile at different depths was being shown. There was also a signalling device which could be driven in the coal pile and when the temperature in the pile rose to 150 deg., the indicator would show that it was time to begin re-piling.

Quite a number of years ago, when I was circulating around the country on construction jobs, I knew an Irish steamfitter who worked for the Pittsburgh Valve, Foundry & Construction Co., who had a wealth of interesting stories which he told in the dialect of the old sod. I asked N. M. Templeton about my old friend, but evidently he has departed for other fields. We were interested in the line of valves which this company showed, and also a method which they used for building welded headers. One of these headers was on exhibi-



33. How to check up on the temperatures of stored coal was demonstrated by The Protectometer Co.
34. Welded headers were shown by the Pittsburgh Valve Foundry & Construction Co.
35. Radojet air pumps were featured by the C. H. Wheeler Mfg. Co.
36. Lea coal meter and a new type of spray nozzle attracted attention at the Yarnall-Waring Co. exhibit

tion, which gave some idea of how the interlocked welded neck is made. Some of the hydraulic valves which they were showing are designed for 2000 lb. working pressure.

Another arrangement of arch design was shown by the Liptak Fire Brick Co., of Minneapolis. Their construction is known as the double suspension combustion and ignition arch and complete details were shown by means of a furnace section which they had erected.

"In what sizes do you build these rado-jet air pumps?" asked Bill, of J. Dobson, of the C. H. Wheeler Mfg. Co. "You may be interested in knowing," replied Mr. Dobson, "that we are building this type of pump for the two airplane carriers "Lexington" and "Saratoga" which are being built for the navy. In both these cases, the air pump will be rated at 180,000 hp." You could have knocked Bill over with a feather, as he had no idea that this type of a pump could be built in sizes so large. This organization was also showing its line of dynamometers, inter and after condensers, Leslie valves, and Sarco temperature regulators.

As we had only two more exhibits to look at in this half of the building, we stopped in for a moment and saw the high lift industrial truck which was being shown by the Baker R. & L. Co., of Cleveland, and then turned to the exhibit of the Olsson Corporation, of New York. Mr. Olsson showed us the details of the gas balance which he has developed for giving a continuous indication of CO_2. This device works on a mechanical principle by measuring the difference in specific gravity of the gas.

As we had heard something about the Lea coal meter, which is well known in England, we were particularly interested in this device at the exhibit of the Yarnall-Waring Co., of Philadelphia. D. R. Yarnall, who showed us around, told us that this meter is for use with chain grates and functions by measuring the depth of the fuel bed and the speed of the grate. "It is necessary," he continued, "to calibrate the meter by weighing the coal for the first run and in this way a constant is obtained, by which the meter reading is multiplied to give the actual tons." Mr. Yarnall also pointed out the involute rigid spray nozzle which they have developed for spray pond work. This nozzle does not have any vanes, and Mr. Yarnall stated that difficulty due to clogging is eliminated. We also looked over the CO_2 recorder and the line of hydraulic valves and air compressor unloaders which they were showing.

Vacuum pumps for either dry or wet operation and a standard double suction centrifugal pump were next shown to us by P. H. Raun, of the Frederick Iron & Steel Co., and on the other side of the aisle the M. T. Davidson Co. were showing their line of pumps. W. E. Brennan, of the Davidson Co., went over a few points on their boiler feed pumps, and also showed us their vertical centrifugal sump pump for motor drive.

Various types of draft gages were shown by Lewis M. Ellison Co., of Chicago. We spent some time in looking these instruments over. Across the way, we looked in on the Martin-Morse Corporation, of New York. This company has worked out a method for inserting a section of lead threads in pipe fittings which it is claimed will reduce leakage. It is possible to take up on the lead section by means of a set screw should a leak develop at any time and in this way the necessity for taking down the pipe line is eliminated. We also looked in on the Hays School of Combustion exhibit to get an idea of the work they are doing.

At the exhibit of the Foxboro Co., of Foxboro, Mass., we were shown the line of recording instruments such as thermometers, pressure gages, draft gages, CO_2 recorders, etc., which are built by this company. As we passed on we stopped for a moment at the exhibit of the Mineral Oil Paint Co. Our study of refractories was continued at the booth of the King Refractories Co., of Buffalo. Samples of their high temperature cements and mono-boiler baffles were shown, as well as an insulating cement. Mr. Smith, who gave us the information, stated that the high temperature cement was used for laying up fire brick in boilers after which a protective coating of the cement is applied to the wall surface.

Continuing on our way, we stopped to see the CO and CO_2 recorders, dial and recording thermometers, absolute mercury pressure and vacuum gages, temperature and pressure regulators, which were shown by the C. J. Tagliabue Mfg. Co., of Brooklyn. Next in line was the Mack Engineering Supply Co., of New York, where brick work for oil burning installations was shown.

Another interesting method of clinker prevention is that which has been worked out by the Drake Non-Clinkering Furnace Block Co., of New York. In this system the blocks contain venturi type nozzles which are said to increase the velocity of air to the fuel bed, thereby increasing the clinker safety zone. In the same booth the Furnace Engineering Co. showed their method of supporting furnace walls.

"Look at the size of that pressure gage," exclaimed Bill, as we saw the jumbo gage which was exhibited by the Ashton Valve Co. "What's the idea of such a large gage?" asked Bill, of C. W. Buckelew. "The idea is," replied Mr. Buckelew, "that such a gage is used as a master pilot gage, and placed so that it can be seen all over the boiler room. You will notice that the dial hand travels about an inch for every pound of pressure and the slightest change in operating conditions will show up at once." Mr. Buckelew also called our attention to the pop safety valves, relief valves, pressure and vacuum gages, gage testing apparatus and whistles which were shown by this company.

At the exhibit of the U. S. Cast Iron Pipe & Foundry Co., we looked at sections of pipe which had been cast in vertical sand moulds, and also at sections which had been made by centrifugal action. Later on we also saw the moving pictures of the work in a pipe foundry. At the Julian d'Este Co. booth, they were featuring a new type of reducing valve with removable internal parts. D. A. Herrick pointed out the advantages of this arrangement, stating that it would be possible at any time to take the parts out and replace one or more without having to go to the trouble of sending the entire reducing valve in to the factory. He also called our attention to the Curtis water regulator and the general line of Curtis specialties.

Next in order was the Philadelphia Gear Works and we looked over the layout of their worm and herringbone gear speed reduction train and continued on to the next exhibit where the Roto Co., of Hartford, Conn., was showing its line of air, steam and water driven tube cleaners for water tube and fire tube boilers of all types. This latter company also showed a section of

condenser tubing, showing how the cleaner cleaned the tubes and also how the air motor works. The Paragon line of cap cleaners and handhole cleaners were also included.

At the next exhibit, that of the S-C Regulator Co., of Fostoria, Ohio, we became much interested in the new type of pump governor which this company is now bringing out. This governor does not use either springs or a lever to maintain the desired pressure difference between the boiler feed and the boiler pressure. Instead, it works on a diaphragm principle. J. M. Barrett, who went over this pump governor with us, stated that the design was such that the pressure feed curve, if superimposed on the boiler pressure curve, would be found to check exactly, showing that there is no appreciable time lag or variation in operation of this governor. This organization also showed their line of S-C feed water regulators.

As our time was growing short we hastened on to the Kingsbury Machine Works exhibit where the Kingsbury thrust bearing was shown, and then continued on

37. Heat insulating materials were shown by the Celite Products Co.

to the exhibit of the McLeod-Henry Co., of Troy, N. Y. This latter company showed samples of their "steel mixture" for boiler settings.

Water treatment was again brought to our attention by the Dearborn Chemical Co., of Chicago. In order to show the wide variation in the amount of solid matter held in water, a number of bottles were shown, each of which contained the residue left from boiling 100 gal. of water. G. Irving, who was in charge of the exhibit, pointed out that this wide variation meant that there was no cure-all for water treatment, and each case would therefore have to be treated after a thorough analysis of the conditions had been made.

Sil-o-cel, a high temperature heat insulating material, was shown by the Celite Products Co., of New York. This material, which is mined in California, is made up in the form of bricks, blocks, powder and plastic cements. One feature of the exhibit was the use of a blow torch to heat up the center section of a brick to show that at no time would the brick become so hot that it could not be handled with the bare hands. We then proceeded on to the exhibit of the Foster Engineering Co., of Newark, N. J., where they were showing their line of valve specialties. Of particular interest was the 8-in. steel automatic non-return valve for 400 lb. pressure and 700 deg. F. temperature, which is a duplicate of the one furnished for the Hell Gate station.

Continuing on our way we looked at the Hays automatic CO_2 recorder in actual operation which was being shown by the Paul B. Huyette Co., of Philadelphia. They were also showing their draft gages and the A-Jacks damper regulator.

As the end of the show was in sight, we decided that we would finish up our somewhat methodical survey and then just float around and look at things in general. With that thought in mind, we came to the exhibit of the Gillis & Geoghegan Co., of New York, where they were showing their telescopic hoist for the removal of ash cans from plants located in the basement of office and other buildings. This hoist may be operated either by hand or electric power and the telescopic mast allows the loading of the cans directly into a truck at the street level. We now spend a few moments at the Lead Lined Iron Pipe Co., of Wakefield, Mass., and the Smith & Serrell Co., of Newark, N. J., exhibit. The latter concern was showing its Keytite self-fitting keys and the Francke line of flexible couplings.

Bill heaved a big sigh and remarked that he was glad the job was completed, although we both felt that it had been well worth while and that we had picked up a lot of interesting and valuable information. "Well, we'll be back next year," remarked Bill as we parted to scout around individually before we finally left the show.

Refrigerating Engineers Consider Technical Problems at Annual Meeting

ALTHOUGH the 18th annual meeting of the American Society of Refrigerating Engineers held at New York on Dec. 4 to 6 was devoted largely to highly technical discussions, much material was presented which will have bearing on the working out of refrigeration problems. Frequently the accuracy of ammonia tables has been questioned, particularly those sections relating to superheated conditions of the vapor. For this reason, the work of the National Bureau of Standards in determining the physical properties of ammonia which was presented by C. S. Cragoe, in the form of tables, aroused marked interest. Another paper which called forth discussion was that presented by J. H. H. Voss, of New York, in which he showed the effect of heat waste in the ammonia compression refrigeration machine.

On the morning of Dec. 4, the first session at the Hotel Astor was a business meeting at which William S. Shipley, of York, Pa., was elected president. Other business which came before this meeting, which was presided over by President Harry Sloan, of Milwaukee, included a discussion of the mechanical refrigeration safety code and the code for unfired pressure vessels.

In the afternoon, the society met with the American Society of Mechanical Engineers, at which time C. S. Robinson, of the Massachusetts Institute of Technology, presented a discussion on the design of cooling towers and Percy Nicholls showed the technical problems involved in the calculation of the economic thickness of insulation in the refrigerating field.

In covering cooling tower design, Professor Robinson pointed out that engineers have designed towers in the past on empirical information and in accordance with the experience of previous successful designs. He

asserted that wide departure from standard designs is difficult because of the lack of scientific basis for design and he therefore presented equations which were applicable to a wider range of working conditions. In order to substantiate these formulas, experimental data were presented.

At the evening session, Harry Sloan in the presidential address pointed out the importance of educating and training the engineer. Besides the paper by Mr. Cragoe, which was given at this time, H. J. Macintire, of the University of Illinois, presented a paper on Flexibility of Cast Iron Radiators for Direct Expansion of Ammonia.

On Dec. 5, the morning session consisted of papers on Performance of Single-Acting Simple Ammonia Compressors and Tubular Condensers, by George A. Horne, and one on Reliability of Fluid Meters in Refrigeration Tests, by L. S. Morse. In the afternoon, W. G. Croll, of Wellington, New Zealand, gave a discussion on Air Batteries as Applied to Refrigeration in New Zealand Meat Works, and W. H. Motz talked on the Compression Refrigerating Cycle. At the session on Dec. 6, Mr. Voss presented his paper and Mr. Macintire described an oscillating compressor for ammonia.

Consolidated Utilities in Indiana Will Be Served by Plant in Coal Field

CONSOLIDATION of electric power and lighting utilities serving 70 cities and towns in central Indiana, has been effected by the Central Indiana Power Co., with headquarters at Indianapolis. It is expected that the interconnections and unit operation of these various plants will reduce the cost of power production.

As a part of the general plans which have been outlined, Stone & Webster, Inc., have been retained as construction engineers for the erection of a new 40,000 kw. steam plant which will be located near Terre Haute on the Wabash River. The site of the proposed plant is on 3400 acres of company owned coal lands which will provide a 70 yr. fuel supply without transportation costs other than local handling.

It is expected that about $12,000,000 will be needed to build the station and to complete the necessary interconnections.

Southern Power Co. Plans $16,000,000 Program for 1923

ANNOUNCEMENT of a construction program involving an investment of approximately $16,000,000, which will be completed by the Southern Power Co. during the coming year, was made by officials recently.

Under the program, two hydroelectric power plants will be built; additions made to two steam electric plants, which will add 200,000 hp. to the company's generating capacity, and 200 mi. of transmission lines and a number of transformers and switching stations constructed.

Two hydroelectric plants are now being built at Mountain Island, Gaston county, North Carolina, where 80,000 hp. will be developed, and at Dearborn Station, Great Falls, S. C., where 60,000 hp. will be obtained. The Mountain Island plant is to be ready for operation by next August, but the Dearborn plant is expected to be completed by March, and the steam plant additions, according to the contracts, will be ready for operation by next September.

Steam plant additions will be at Mount Holly, N. C., where 40,000 hp. will be added; and at Eno, University Station, N. C., increasing that plant's capacity 20,000 hp.

Approximately 200 mi. of new transmission lines, which, not including substation and switching equipment, will represent an investment of more than $2,000,000, will be completed during the early summer, it was stated.

New Year Will See Large Development in the Carolinas

More than $6,000,000 will be required to complete developments outlined for 1923 by the Carolina Power Co., the Carolina Power and Light Co. and its affiliated companies, including the Yadkin River Power Co. and the Palmetto Power Co., according to a recent announcement by officials of the Carolina group.

This program includes the construction by the power company of a 15,000-kw. steam plant near Brickhaven on the Cape Fear River, which, it is expected, will be in service by Sept. 1, 1922. The plant, which will be within 30 mi. of Raleigh, will be constructed for an ultimate capacity of 60,000 kw. and will be used for the purpose of supplementing power furnished by the hydroelectric plants of the Carolina group during low water periods. Its completion will make available a large block of primary power through the conversion of secondary power, officials state.

Japanese Engineer Comments on Hydroelectric Progress in Nippon

ON A THREE months' tour of the United States to study various hydroelectric operations, Yasushigo Hayashi, electrical engineer of Osaka, Japan, arrived in San Francisco recently and visited the Pit River power project of the Pacific Gas and Electric Co.

Mr. Hayashi is managing director of the Uji River Electric Co. and vice-chairman of the board of directors of the Nippon Electric Power Corporation, which concerns supply power to the entire vicinity of the cities of Kobe, Osaka and Kioto. He is a member of the Osaka Chamber of Commerce.

Plans to construct more stations are now under way by both companies, which are associated in the harnessing of the Uji River, he said. The total amount involved in this work was stated to be over $65,000,000, and when completed will be the biggest power project in operation in the Orient and on the European continent.

"There is not much to be learned from studying the power system in Europe," Mr. Hayashi declared, "but I have found plenty to study in the United States, as this country leads the world in hydroelectric operations.

"I believe more people use electricity in Japan than in the United States," he continued. "This is due to the fact that we have no oil to burn, and as for gas, it is too expensive to be generally available. Even the poorest people in the smallest villages of Japan use electricity. I am surprised to see so much power going to waste in the United States."